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THESIS

COMPOSITE STRUCTURAL RELIABILITY CALCULATION BY FINITE ELEMENT AND STATISTICAL STRENGTH THEORY

by

Pattama Suttisornyotin

March 1986

Thesis Advisor: E.M. Wu

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T227294

REPORT DOCUMENTATION PAGE

a REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
a. SECURITY CLASSIFICATION AUTHORITY b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release, distribution is unlimited
PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)

a. NAME OF PERFORMING ORGANIZATION Naval Posgraduate School	6b OFFICE SYMBOL (If applicable) Code 67	7a. NAME OF MONITORING ORGANIZATION Naval Posgraduate School
c. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5100		7b. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5100
. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

. ADDRESS (City, State, and ZIP Code)

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

TITLE (Include Security Classification)

)MPOSITE STRUCTURAL RELIABILITY CALCULATION BY FINITE ELEMENT AND STATISTICAL STRENGTH
IEORY

PERSONAL AUTHOR(S)

Pattama Suttisornvotin

a TYPE OF REPORT sters Thesis	13b TIME COVERED FROM ________ TO ________	14 DATE OF REPORT (Year, Month, Day) 1986 March	15 PAGE COUNT 86

SUPPLEMENTARY NOTATION

COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Finite element, statistical strength theory, shape parameter, scale parameter

ABSTRACT (Continue on reverse if necessary and identify by block number)

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DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION unclassified	
NAME OF RESPONSIBLE INDIVIDUAL dward M. Wu	22b TELEPHONE (Include Area Code) 646-3459	22c OFFICE SYMBOL 67-Wt

FORM 1473, 84 MAR

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Composite Structural Reliability Calculation by Finite Element and Statistical Strength Theory

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1986

ABSTRACT

The reliability of the structure can be calculated by combining the non-uniform stress distribution of a structure from finite element analysis with the statistical strength theory under two dimensional non-homogeneous, uniaxial stress limitations. The specimen models with and without notch are the sample structures to illustrate the calculations. The statistical strength of the structure is cast in the standard Weibull form characterized by the structural scale parameter, β_E and shape parameter, α_E which are functions of the material scale and shape parameters (α and β.) Therefore, this thesis demonstrated that the scale parameter of the structure remains constant for different load magnitude, only the structural geometry and loading condition cause the change of material scale parameter, β to the structural scale parameter, β_E. The results also shows that the degree of uniformity of stress within structural element and the linearity of the load magnitude and stress distribution within the structure affect the accuracy for the calculation.

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LIST OF SYMBOLS

δV	Infinitesimal volume (Equ. 2.1)
f	Probability of failure (Equ. 2.1)
δf	Probability of failure of infinitesimal volume δV (Equ. 2.1)
Ψ	Failure parameter (Equ. 2.1)
σ_{ij}	Stress in volume δV (Equ. 2.1)
$\Psi [\sigma_{ij}]$	Ψ is a function of σ_{ij}
$\sigma_{ij} [x]$	σ_{ij} is a function of position x
R	Reliability
δR	Reliability of infinitesimal volume δV (Equ. 2.2)
Σ	Summation
$\int$	Integration
Π	Product
$\lim$	limit
N	Number of δV_k in volume V
$\propto$	Shape parameter of material
$\propto_E$	Scale parameter of structure

β	scale parameter of material
β_E	Scale parameter of structure (same as BETAA in statistical program)
$\sigma_x{}^p$	Homogeneous stress in x-direction within p^{th} link
ϵ	arbitrarily small value
l_p	length of p^{th} link
σ_p	Element stress is calculable from given boundary condition
$\sigma_p[P]$	σ_p is a function of P
P	Arbitrary magnitude in linear system
$\{P\}$	Stress vector due to the same boundary condition as P (same as PBAR in statistical programs)
F	Conversion factor calculable for finite element analysis (one dimensional, non-homogeneous, uniaxial stress)
$\sigma_x{}^{pq}$	Homogeneous stress within pq^{th} element
k_c	Critical stress intensity factor
a_c	Critical crack length
R_L	Reliability of length L
R_E	Reliability of structure

j	Number of link or length of element within total length of link or total length of model respectively
k	Number of width of element within total width of model
jk	number of overall element within model (j multiply by k)
E_{ij}	Orthotropic modulus
ν_{ij}	Orthotropic Poisson's ratio
G_{ij}	Orthotropic shear modulus

ACKNOWLEDGEMENTS

The author would like to gratefully thank to the thesis adviser Dr. Edward M. Wu for his help and his care for this thesis. This thesis would not be complete without his idea and his knowledge as well as his generous availability of computer and facilities.

Special thanks are also given to:

Dr. J. O. Hallquist and Dr. S. C. Chou , for their help in the finite element analysis which is one part of this thesis ,

Dr. Shi-Hau Own , for his help in statistical strength theory , and

Computer Science Department, for technical assistances and computer facilities.

I. INTRODUCTION

A. RELIABILITY REQUIREMENT FOR COMPOSITE STRUCTURES

Reliability theory became an independent scientific discipline at the beginning of the 1950's under the influence of the rapid development of radio electronics, computer, devices, and rocketry. Modern radio electronic apparatus and digital mechanics consist of a very large quantity of components. If the failure of one component leads to the failure of the unit as whole, then evidently the possibility of high reliability (freedom from failures) will diminish rapidly as the unit becomes more complex. In this connection, problems arise on the prediction of the reliability of planned units, on the development of measures to increase the reliability, on a fundamental for reliability testing methods, etc. All these questions are the subject of reliability theory.

The mechanical strength and stiffness of a structure are one of the aspects of reliability. The engineering design concept is not only solving the stresses and strains which originate in structures under various external imposed conditions but also trying to make them to be operated sufficiently reliably throughout their established utilization time. Therefore, in the concluding stages of an engineering design structural mechanics inevitably comes into resolution with reliability theory. For critical application of composite as an aircraft structure, the study of reliability in composite structures is required.

B. HISTORICAL BACKGROUND

Bullock [Ref. 1] used Weibull theory to predict the strength of the composite materials between different laboratory sample configurations. He investigated the strength ratios of composite materials in flexure and in tension. He assumed the shape parameter (the exponent characterize flaw-density that determines the scatter of strength of the material) was not changed when the geometry or size of the material was changed. He used the same shape parameter for the tensile test and flexure test which based on homogeneous state of stress and heterogeneous state of stress respectively. He found, however, based on the experimental results, the hypothesis that the shape parameter was constant was not realistic. Changes in shape parameter were in fact observed. Whitney and Knight, M [Ref. 2] used a statistical strength theory based on Weibull distribution to explain the difference between unidirectional tensile data generated from a flexure test and a standard tensile coupon. The result was shown a significantly larger variation in tensile strength versus flexural strength.

Rosen [Ref. 3] presented a theoretical and experimental treatment of the failure of composites, consisting of a matrix stiffened by uniaxially oriented fibers, when subjected to a uniaxial tensile load parallel to the fiber direction. He observed that a portion of the fiber at each end was not fully effective in resisting the applied load because of the axial load was transmitted by shear through the matrix to adjacent fibers. Basically, the fibers failed as a result of a statistically distributed flaws or imperfections and composites failed as a result of a statistical accumulation of such flaws over a given region. Therefore, the ineffective length of the fiber was introduced in order to consider the composite to be composed of a series of layers of this length. Then the segment of a fiber within a layer might be considered as a link in the chain that contribute the fiber. Each layer was then a bundle of such links, and the composite as whole can be modeled by series of such bundles. Weibull theory was used to define a statistical distribution of flaw or imperfections that result in fiber failure under applied stress. The statistical accumulation of such flaws within a composite material was demonstrated to be cause of composites failure. He concluded that the stress concentrations occurred in fiber adjacent to the fibers break were considered only to balance the effect of the variation of ineffective length which affect to the composite strength. Knight, C.E. [Ref. 4] used a finite element stress analysis and statistical strength theory to assess the influence of the stress concentration on the ultimate strength calculation for composites from the Split-D Test. He observed that the geometry changed causes the nonlinearity and the boundary condition would be changed.

The Probabilistic Statistic Failure of Composite Materials [Ref. 5] demonstrated how to develop a theory that combined the statistics of composite material failure with the orthotropic nature of composite materials. The effects of loading history and the probabilistic location of the failure for a composite can be accounted using this theory. In order to improve the efficiency of composite designs for structural analysis, a theory that combining the statistics of the experimental failure data with an orthotropic material failure response was developed. The analytical theory developed extent deterministic failure laws to include the statistical scatter observed experimentally. Tsai and Wu [Ref. 6] are one of the investigators who described a general theory for the failure of composite materials as the strength tensor theory but determining is complicated by wide range in failure properties of composite materials and scatter in experimental results. The Weibull weakest link theory was developed and described a description of the spatial distribution of the failure locations with a sample calculation performed for the case of a uniformly loaded tensile specimen. Three point bending specimens were used to predict failure location by applying the basic weakest link theory. Four point bending specimens were used to illustrate the effect of loading history which were evaluated by applying numerical integration to the probability of failure density distribution curves. The compressive failure load was demonstrated that it is not deterministic failure and also having some scatter which is independent of tensile scatter so that the Weibull failure distribution for tension and compression are different.

In ordinary structures having many stress components active, a decision on the probability for survival must be based on statistical descriptions that admit multiaxial stress. The development of combining weakest link theory with the strength tensor representation is required.

C. OBJECTIVE AND SCOPE

The driving motivation for this research is that many critical components of modern aircraft structure are made of composite materials. However, the reliability design is necessary for engineering designs requires not only the stress analysis but also statistical theory of failure strength of composites, The latter motivated the investigation of statistical theory for composites failure strength where are summarized in the last section. Any aircraft structural components inevitability have the non-uniform stress in the neighborhood of edge-notches and holes. Size effect is the one that is importance for the composite study because of the difficulty and the economy that one could not experiment the several large samples to predict the reliability of the components. Even the experimental test samples can be made, the difficulty to identify the failure location is also impossible. Finite element method and the statistical theory can be combined to explore the possibility of prediction both the reliability of the structure and the failure location. Basically, finite element method can be used to calculate the stress distribution that occurs in the structure under an arbitrary loading boundary condition. The structure is divided into elements be sufficiently small that the stress is uniform. This solution of physically continuous system can then be replaced by the solution of the discrete system of the elements. The statistic Weibull theory can be used to model composite materials composing of a series of bundles which are in turn composited series of fiber links. Another assumption for the statistical Weibull theory is the local stress in each link must be uniform. For the connection to the two dimensional finite element method, instead of using link, the element will be introduced. For one dimensional case, the link can be used but in two dimensional case, the element has a width. The operation of size effect formulation based on Weibull theory and finite element method will be presented in next chapter.

The scope of this research limits to the treatment of statistical strength of composite structures which are two dimensional, subjected to nonhomogeneous uniaxial stress including size effect. The specimen models are plate with and without notch subjected to the tensile displacement loading case. The finite element code name NIKE2D [Ref. 7] is used. NIKE2D is a two dimensional finite element program which is developed by Hallquist, J.O. [Ref. 7]. It can be used to calculate linear and non-linear finite element problems. In this thesis, only the linear portion is utilized. MAZE [REf. 8] computer program is used to generate specimen model, grid, define boundary conditions, and also create the input file that can be immediately use for NIKE2D program. ORION [Ref. 9] is the post processing of NIKE2D which can be used to create contour curves of stress, displacement, etc. The observation of uniform stress in each element will be made. The observation of using half of the entire model by symmetrical will be made, which bases on the idea that the model can be divided into smaller elements when compare to the entire model. The linear relationship between external loads and the local stress in each element will be verified. The plate without notch is used as bench mark to compare the reliability results to the plate with notch. The specimen model dimension bases on specimen dimension which using in the shear test experiment. The shear model that involves with the multiaxial stress which can not yet be treated in this thesis. Future work requires generalization of current results to multiaxial stress. When such extension is made, realistic prediction of composite structures will then be possible.

II. STATISTICAL MODEL OPERATION

A. REVIEW OF WEIBULL WEAKEST LINK FAILURE THEORY

consider an infinitesimal volume element δV at point x and subjected to stress state σ_{ij}. The probability of failure δf of volume element δV is assumed to be given by:

$$\delta f = \Psi [\sigma_{ij} [x]] \delta V \qquad (2.1)$$

where: Ψ = failure parameter which is a function of σ_{ij} which is a function of position, x.

It is assumed there are only two possible states for the volume element, δV, either the volume element survives the loads or fails. From this assumption the probability for survival or reliability is simply:

$$\delta R = 1 - \delta f = 1 - \Psi[\sigma_{ij} [x]] \delta V \qquad (2.2)$$

The basic assumption in weakest link theory is: If any volume, δV, in the total structure volume, V, fails, then the entire structure occupying volume V fails.

Consider the structural volume, V, to be divided into N volume elements δV_k, with each of the volume elements located at point x_k.

Then the total volume is given by:

$$V = \lim \Sigma \ \delta V_k = \int_V dV; \qquad k = 1, 2 \ldots N \qquad (2.3)$$

where: $N \to \infty$

The probability for the volume V to survive, R, under weakest link theory, is given by:

$$R = \lim \Pi \ \delta R_k = \lim \Pi \ \{ 1 - \Psi[\sigma_{ij}[x_k]] \delta V_k \} \qquad (2.4)$$

where: $k = 1, 2 \ldots N$, and

$N \rightarrow \infty$.

Equation 2.4 can be equivalently written as:

$$\ln R = \lim \ \Sigma \ \ln \{ 1 - \Psi[\sigma_{ij}[x_k] \delta V_k \} \qquad (2.5)$$

where: $k = 1, 2 \ldots N$, and

$N \rightarrow \infty$

The quantity $\Psi . \delta V_k$ is small and from the Taylor series expansion

$$\ln (1 + x) \cong x \qquad \text{for } x << 1$$

Equation 2.5 becomes:

$$\ln R = \lim \ \Sigma \ -\{ \Psi[\sigma_{ij}[x_k]] \delta V_k \} \qquad (2.6)$$

or

$$R = \exp -\{ \int_V \Psi[\sigma_{ij}[x_k]] dV \} \qquad (2.7)$$

where: $k = 1, 2 \ldots N$, and

$N \rightarrow \infty$

Equation 2.7 is the basic equation derived under the assumption of weakest link theory. Note that the stress distribution need not to be uniform; the material can be generally anisotropic and the material can be non-homogeneous. The equation is limited in that it describes only the reliability of the entire structure and provides only a quantitative description of where the structure will fail. The reliability becomes:

$$R = \exp - \{ \sigma_{ij} / \beta \}^{\alpha}$$

where: α = shape parameter, and

β = scale parameter

In the next section, basic theory will be used to obtain the formulation of size-effect for one dimensional, non-homogeneous, uniaxial stress.

B. SIZE-EFFECT FOR NON-HOMOGENEOUS STRESS, ONE DIMENSIONAL, UNIAXIAL STRESS

The value of α_{L1} and β_{L1} are estimated by the experimental procedure from the given n numbers of sample length L1. For a sample length L, the evaluation of α_L and β_L can be implemented according to the following procedure.

There are j links in length L (Figure 2.1-a) each links are not necessarily of equal length, but the stress in each link is homogeneous,ie the stress σ_x^p within the p^{th} link satisfies the following condition:

$$x\sigma_x^p - \{\textstyle\int_{lp} x\sigma_x dx\}/l_p \leqslant \epsilon \qquad (2.8)$$

where: ϵ can be any arbitrarily small value

l_p = length of p^{th} link

$p = 1, 2 \ldots j$

The reliability for each link is:

$$R_p(\sigma_x^p) = 1 - f(\sigma_x^p) = \exp -(\sigma_x^p/\beta_p)^{\alpha_p} \qquad (2.9)$$

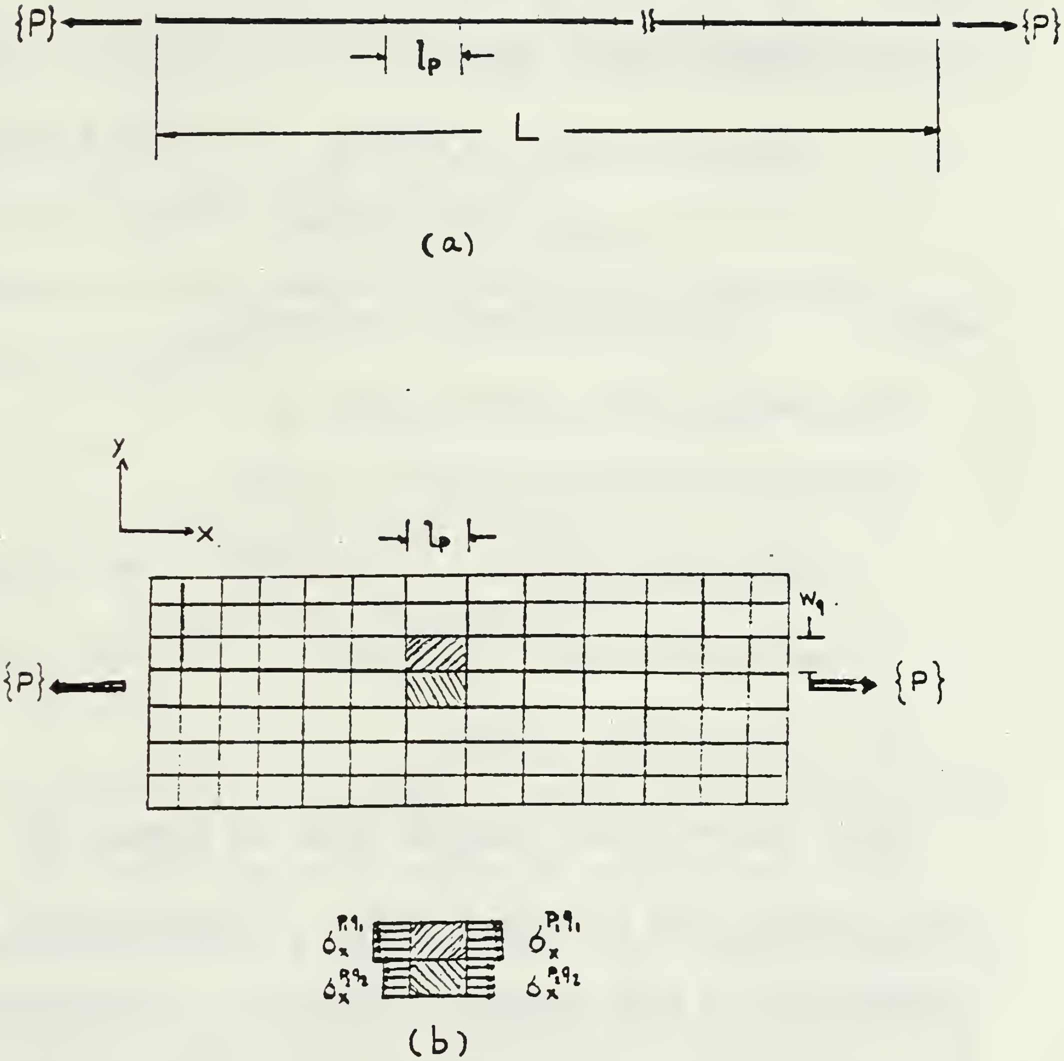


Figure 2.1 (a) One Dimensional Links Configuration
(b) Two Dimensional Specimen Configuration

There are $(l_p/1)$ unit links within l_p, the reliability of each unit link within l_p is:

$$R_p(\sigma_x{}^p) = \exp -(\sigma_x{}^p/\beta)^{\alpha} \qquad (2.10)$$

where: α and β for unit link are material constants

The reliability for each link l_p is:

$$R_p(\sigma_x{}^p) = \Pi\,\{\exp -(\sigma_x{}^p/\beta)^{\alpha}\}_m \qquad ; m = 1, 2 \ldots (l_p/1)$$

$$= \exp\{-(l_p/1)(\sigma_x{}^p/\beta)^{\alpha}\}$$

where: $(l_p/1)$ is the number of unit link in l_p

The reliability for then entire length L is:

$$R_L = R_1(\sigma_1)\,R_2(\sigma_2)\,R_3(\sigma_3)\,R_4(\sigma_4)\ldots R_j(\sigma_j)$$

$$= \exp\{-(l_1/1)(\sigma_1/\beta)^{\alpha}\}\exp\{-(l_2/1)(\sigma_2/\beta)^{\alpha}\}\ldots\exp\{-(l_j/1)(\sigma_j/\beta)^{\alpha}\}$$

$$= \exp -\{(l_1/1)(\sigma_1/\beta)^{\alpha} + (l_2/1)(\sigma_2/\beta)^{\alpha} + \ldots + (l_j/1)(\sigma_j/\beta)^{\alpha}\}$$

$$R_L = \exp -\{\Sigma\,[(l_p/1)(\sigma_x{}^p/\beta)^{\alpha}]\} \qquad ; p = 1, 2 \ldots j \qquad (2.11)$$

Under uniform stress condition within an element, let σ_p is the element stress which is constant within $l_p{}^{th}$ length element and σ_p is calculable from a given boundary condition (B.C.) characterizable by {P}, (eg, a load vector). The stress due to the same B.C. with a different magnitude P is:

$$\sigma_p[P] = \sigma_p[\{P\}]\,(P/\{P\}) \qquad (2.12)$$

where: P can be of any arbitrary magnitude in linear system, or

P is of neighboring magnitude of local linear system.

$\sigma_p[\{P\}]$ is expressible from structural mechanics calculations, (eg, a finite element method.)

In order to reduce the value of $\sigma_x{}^P$ which is a function of P in equation 2.11 to a single random variable $\{P\}$, the substitution of $\sigma_x{}^P[P]$ by $\sigma_x{}^P[\{P\}]$ is made within the same manner as the expression in equation 2.12. Thus, the equation 2.11 becomes:

$$R_L = \exp -\{ \Sigma [(l_p/l)(\sigma_x{}^P[\{P\}]/\{P\})^{\alpha}(P/\beta)^{\alpha}] \} \qquad ; p = 1, 2 \ldots j$$

Expressing the above equation into the Standard Weibull form:

$$R_L = \exp -\{ (P/\beta_L)^{\alpha_L} \}$$

Then: $\alpha_L = \alpha$

$$\beta_L = \beta / \{ \Sigma [(l_p/l)(\sigma_x{}^P[\{P\}]/\{P\})^{\alpha}] \}^{1/\alpha} \qquad ; p = 1, 2 \ldots j$$

Let: $$F = \{ \Sigma [(l_p/l)^{1/\alpha} (\sigma_x{}^P[\{P\}]/\{P\})]^{\alpha} \}^{-1/\alpha} \qquad ; p = 1, 2 \ldots j$$

Thus: $\beta_L = \beta F$

That is, given a structure of length L subjected to boundary condition parameter $\{P\}$ (which may be of a single or multiple load P_1, P_2, . . . vectors characterizable by a single parameter $\{P\}$) which give rise to a unidirectional stress σ_p computable from the methods of mechanics (eg, finite element analysis). l_p are element lengths which are segmented as small as necessary to assume the stress to be uniform. Upon sampling n structures measuring P_n failure loads.

α_L , β_L are shape and scale parameters (in dimension of load estimated from $D(P_n)$ and structural size L .

α , β are shape and scale parameters (in dimension of stress which are geometric independent material parameters).

F is a conversion factor calculable for structural (finite element) analysis.

For special case, homogeneous, one dimensional uniaxial stress:

From: $F = \{ \Sigma [(l_p/1)^{1/\alpha} (\sigma_x{}^p[\{P\}]/\{P\})]^\alpha \}^{-1/\alpha}$; $p = 1, 2 \ldots j$

For $\sigma_x{}^p = \sigma$ and $\{P\} = P_n$:

$$F = [(\sigma/P_n)^\alpha \{ \Sigma (l_p/1)^{1/\alpha} \}^\alpha]^{-1/\alpha} \qquad ; p = 1, 2 \ldots j$$

$$= [(\sigma/P_n) \{ \Sigma (l_p/1)^{1/\alpha} \}]^{-1} \qquad ; p = 1, 2 \ldots j$$

$$= (\sigma/P_n)^{-1} (L/1)^{-1/\alpha}$$

Thus:

$$R_L = \exp -\{ [(P/\beta)/(\sigma/P_n)^{-1} /(L/1)^{-1/\alpha}]^\alpha \}$$

$$= \exp -\{ (L/1) [(\sigma/\beta)(P/P_n)]^\alpha \}$$

This recovers the well known classical result demonstrates the consistency of the current formulation is true.

For each given non-homogeneous boundary condition, a corresponding correction factor F can be calculated by finite element such that the size effect can be predicted. By weakest link in length X ; it is inferred that the plane of facture is perpendicular to X . That means the failure plane has no thickness. Since the one dimension specimen has no width, fracture width is not a parameter.

C. SIZE-EFFECT FOR NON-HOMOGENEOUS STRESS, TWO DIMENSIONAL, UNIAXIAL STRESS

This is the extension of one dimensional, uniaxial stress to two dimensional uniaxial stress. The definition that uniaxial stress implies failure has zero dimension in X direction is adopted for one dimensional, uniaxial stress , which has been described in the previous section. For two dimensional, uniaxial stress, failure automatically requires definition of the failure plane because the specimen has dimension in Y direction (Figure 2.1-b), and it is no longer conceptually a point as in the one dimensional case. In the similarly procedure as in one dimensional case, the specimen is divided into sufficiently small areas within which the stress in direction of force is assumed to be uniform. It is seen that not only the length of the specimen is divided into small element lengths but also the width must be divided into small element widths in order to provide element areas which are satisfies uniform stress assumption. Thus:

$$x\sigma_x{}^p - {}_{lp}\int x\sigma_x dx/l_p \leq \epsilon_x \qquad \text{for all } l_p$$

where: $p = 1, 2 \ldots j$

$$y\sigma_x{}^p - {}_{wq}\int y\sigma_x dy/w_q \leq \epsilon_y \qquad \text{for all } w_q$$

where: $q = 1, 2 \ldots k$

Weakest link in X direction is defined by Eq. 2.8 and unit length in X direction is defined by Eq. 2.9.

Weakest link in Y direction is:

$$R_q[\sigma_x{}^{pq}] = \exp -\{\sigma_x{}^{pq}/\beta_{pq}\}^{\alpha_{pq}}$$

where: $\sigma_x{}^{pq}$ is stress in the q^{th} element, and $q = 1, 2 \ldots k$

This means that if any one of the q^{th} fail, all elements fail. However, the unit (metric) width can not be arbitrarily defined. It is visualized that within each metric area, there is one domineering crack (largest crack perpendicular to σ_x). When subjected to $\sigma_x{}^{pq}$, the domineering crack extends without bound. From fracture mechanics:

$$k_c = \sigma\sqrt{a_c}$$

where: k_c is a material constant and can be independently measured.

a_c is weakest link in Y direction, which can be used as the unit metric width.

Thus: $a_c{}^{pq} = (k_c/\sigma_x{}^{pq})^2$ for element pq^{th}

As well as the division of length element l_p into unit length, the division of width element is necessary. In stead of unit length 1, $a_c{}^{pq}$ is used in order to indicate the critical width in each element. thus, the reliability of entire element is:

$$R_{pq}[\sigma_x{}^{pq}] = \exp -\{ (l_{pq}/1)(w_{pq}/a_c{}^{pq})(\sigma_x{}^{pq}/\beta)^{\alpha} \}$$

$$= \exp -\{ (l_{pq}/1)[w_{pq}/(k_c/\sigma_x{}^{pq})^2](\sigma_x{}^{pq}/\beta)^{\alpha} \}$$

$$= \exp -\{ (l_{pq}/1)(w_{pq}/k_c{}^2)(\sigma_x{}^{pq})^{2+\alpha}/\beta^{\alpha} \}$$

where: $pq = 1, 2 \ldots jk$ (subscript is changed from two dimensional array into one dimensional array.)

The reliability of entire specimen (which is the structure) is:

$$R_E = R_1\ R_2\ R_3 \ldots R_{jk}$$

$$= \exp -\{ \Sigma\, (l_{pq}/l)(w_{pq}/K^2)(\sigma_x{}^{pq})^{2+\alpha}/\beta^{\alpha} \}\ ,\ pq = 1, 2 \ldots jk$$

From the linear relationship between external load and local stresses:

$$\sigma_x{}^{pq}[P] = \sigma_x{}^{pq}[\{P\}]\,(P/\{P\})$$

where: $\sigma_x{}^{pq}[\{P\}]$ is element stress which is calculated under certain loading boundary condition while the magnitude of load is $\{P\}$.

$\sigma_x{}^{pq}[P]$ is element stress which subjected to the same boundary condition as above but different in magnitude, the magnitude is P.

Thus: $R_E = \exp -\{ \Sigma\, (l_{pq}/l)(w_{pq}/k_c{}^2)((P/\{P\})\sigma_x{}^{pq}[\{P\}])^{2+\alpha}/\beta^{\alpha} \}$

where: $pq = 1, 2 \ldots jk$

Express it in term of the Standard Weibull for the structure, thus:

$$R_E = \exp -\{ (P/\beta_E)^{\alpha_E} \qquad (2.13)$$

where: $\alpha_E = \alpha + 2$

$$\beta_E = \{P\}\beta^{(\alpha/\alpha+2)}\{ \Sigma\, (l_{pq}/l)(w_{pq}/k_c{}^2)(\sigma_x{}^{pq}[\{P\}])^{\alpha+2} \}^{(-1/(\alpha+2))}$$

where: $pq = 1, 2 \ldots jk$ (2.14)

The values of α and β of material are altered by the boundary condition and the geometry of the specimen (or structure) changed but they do not depend on the changed of the magnitude of the load. Therefore, the shape parameter, α and the scale parameter, β can be solved for any given structural geometry and boundary condition. The finite element method can be used to calculate the stress distribution of the specimen by dividing the specimen into small elements within which the stress element is uniform.

For the simple limiting 2-D case, the specimen without notch, the stress distribution for entire specimen is uniform. Thus:

$$\sigma_x^{pq} = \sigma_x = \text{constant}$$

$$\beta_E = (\{P\}/\sigma_x)\ \beta^{(\alpha/\alpha+2)} k_c^{(2/\alpha+2)} \{\ \Sigma\ [l_{pq} w_{pq}]\ \}^{(-1/\alpha+2)}$$

$$= \{P\}\ k_c^{(2/\alpha_E)}\ \beta^{(\alpha/\alpha_E)}/\sigma_x A^{(1/\alpha_E)}$$

where: $A = \Sigma [\ l_{pq} w_{pq}\ ]$, $pq = 1, 2 \ldots jk$

$\alpha_E = \alpha+2$

Thus: $$R_E = \exp -\{\ (A/k_c^2)\ (P/\{P\})\ (\sigma_x/\beta^{\alpha})\ \}^{\alpha_E} \qquad (\ 2.15\ )$$

III. APPROACH TO THE PROBLEM

A. SPECIMEN MODEL CONFIGURATION AND COORDINATE SYSTEM

The specimen model has 1.99 " in length and 0.968" in width is align in the y-z plane, (cartesian right hand coordinate system is used). The configuration and the coordinate of the specimen without notched and the plate with 90 degree notch configuration are shown in Figure 3.1. The fiber direction which makes the orthotropic material having large elastic modulus (E_{11}) is considered to be along the y-axis (Figure 3.2).

B. FINITE ELEMENT PROCEDURE

1. Material Constants

The finite element program requires defining the material constants [Ref. 7] for orthotropic elastic to be used in stiffness matrix calculation. The material constants of typical graphite epoxy composite which used in this thesis are:

E_{11} = 18.65 Msi (Mega Pound per square inch)

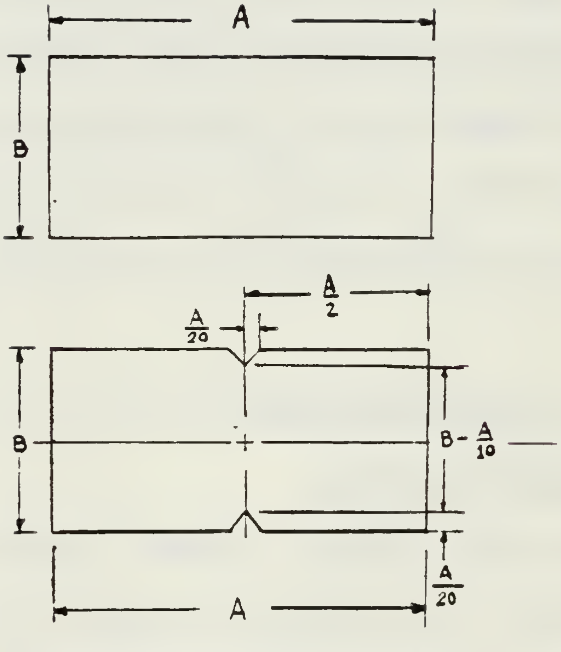
E_{22} = 1.21 Msi

E_{33} = 1.21 Msi

υ_{21} = 0.0339

υ_{31} = 0.0339

υ_{32} = 0.4



A = 1.99" B = 0.968"

Figure 3.1 Dimension of Specimen Models without Notch and with Notch

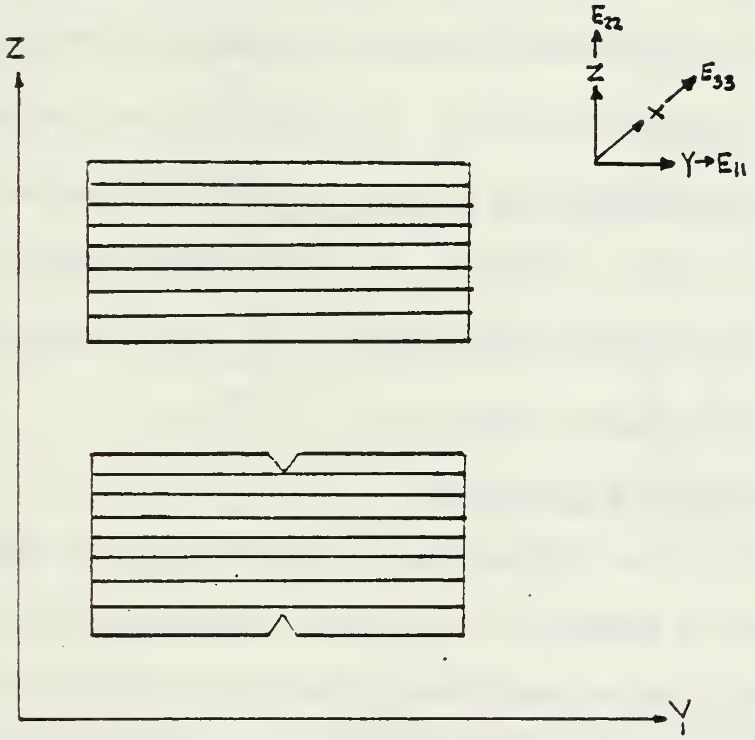


Figure 3.2 Specimen Models Coordinate System

G_{12} = 0.84 Msi

2. Boundary Conditions

The specimen model is subjected to the displacement boundary condition (B.C.) in order to be able to use the entire specimen model in the calculation. An original problem the specimen model is subjected to the displacement B.C. value u_1 (Figure 3.3) on the right hand side in the positive y-direction and the left hand side is subjected to the displacement B.C. value u_1 in opposite direction. In order to fix the specimen model from rigid body displacement, the left side of the model must be constraint in the direction of load. Therefore, the displacement value on the right side of the model becomes two time of u_1. The transform of the displacement B.C. is shown in Figure 3.4.

3. Data Planning and Purposes

NIKE2D is two dimensional axis symmetry finite element code that the thickness is assumed to be infinite. The plane strain analysis is used by assuming no displacement along x-axis and no rotation around y and z axis, which it is satisfy for this purpose. There are eight finite element program data output to be discussed in this thesis:

3.1 Specimen model without notch subjected to the displacement B.C. value 0.01"

3.2 Same specimen as 3.1 but the displacement B.C. value is 0.001". The purpose of these two cases is to demonstrate that there is no stress concentration along displacement direction and the linear relationship between displacement and local stress.

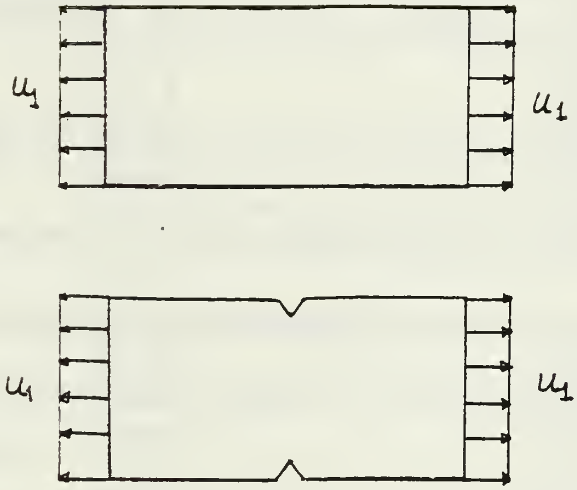
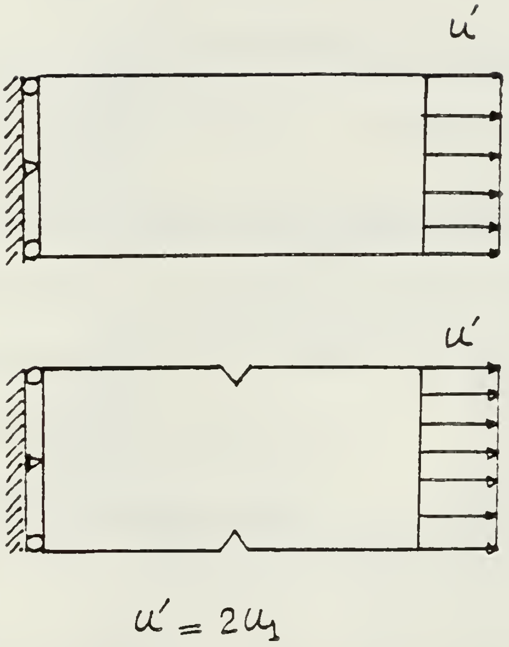


Figure 3.3 Displacement Boundary Condition



$$u' = 2u_1$$

Figure 3.4 Transformation of Displacement Boundary Condition

3.3 Specimen model with notch subjected to the displacement B.C. value 0.01" and the stress calculation bases on four-point integration (Ref. 7) in order to observe the uniform stress in each element.

3.4 The same as 3.3 but the calculation bases on one-point integration at the centroid of each element.

3.5 Half of the specimen model with notch subjected to the displacement B.C. value 0.01" and four-point integration is used. This case will be used to compare with the entire specimen model in order to insure that the half specimen can be used because of the symmetrical configuration.

3.6 Same as 3.5, but one-point integration is used.

3.7 Same as 3.6, but the displacement B.C. value is 0.004.

3.8 Same as 3.6, but the displacement B.C. value is 0.001.

One-point integration results will be used to be input data for statistical program.

C. STATISTICAL PROCEDURE

After obtaining the results from the finite element program, four-point integration results have to be considered to insure that the tensile stress in each element is uniform or almost uniform. If they are not uniform, the size of the element need to be reduced. However, due to computer memory limitation, absolute uniform stress may not be attainable. One should realize that what spatial domain that the element size should be reduced and what area the element need not be changed. The symmetrical of the model can be considered to be used only half of the entire model in order to increase the number of elements.

The statistical size effect in two dimensional, non-homogeneous, uniaxial stress program in fortran 77 is written to be used to calculate the reliability of the specimen models by using the finite element results and shape parameter, α and scale parameter, β from several numbers of certain sample size. There is one program including: 1) the specimen model without notch, 2) the entire specimen model with notch, and 3) the half (top side) specimen model with notch.

This program is presented in Appendix A. There are 12 output data files which are shown in Table 4.3.

IV. DISCUSSION AND CONCLUSION

A. EXAMINATION FOR UNIFORMITY OF UNIFORM STRESS WITHIN ELEMENT

The four-point integration are obtained in entire and half specimen models subjected to the displacement boundary condition (B.C.) value 0.01. For the full specimen model, the element number 544 (shade in Figure 4.1) is considered, the tensile stress values can be read in figure 4.2 ,where the stresses of this element are tabulated under rows 2173, 2174, 2175, and 2176 (relatable to the element by dividing the last number by 4 recovering 544) and the tensile stresses are 0.03663 Msi, 0.03738 Msi, 0.01933 Msi, and 0.01851 Msi (Figure 4.2) respectively, which demonstrated that the stress within element is not exactly uniform but the differences are small. The element number of the half specimen model at the same position as element number 544 of the full specimen is 442 (shade in Figure 4.3) and the tensile stress can be read in Figure 4.4, where the row numbers are 1765, 1766, 1767, and 1768 and the tensile stresses are 0.03667 Msi, 0.03742 Msi, 0.01937 Msi, and 0.01861 Msi respectively, again they are not exactly uniform but the differences are small. The element number 192 in Figure 4.5 (full specimen model) is outside the notch region, the tensile stress values can be read in Figure 4.6, where the row numbers are 765, 766, 767, and 768 and the tensile stresses are 0.06891 Msi, 0.06888 Msi, 0.06852 Msi, and 0.06855 Msi respectively , which shown that the stress within element is not uniform but the differences are more uniform than element in the notch region. The element number of the half specimen model at the same position as element number 192 of the full specimen is 230 (Figure 4.7) and the tensile stress can be read in Figure 4.8, where the row numbers are 917, 918, 919, and 920 and the tensile stresses are 0.06906 Msi, 0.06905 Msi, 0.06871 Msi, and 0.06872 Msi, while they are not exactly uniform but the differences are also smaller than the element in the notch region. In principle the stress in each element may approach uniformity by decreasing the size of the element. This will increase the number of the elements and is limited only by the computer memory and computation time. The observation of symmetrical model is obvious from the stress values of full specimen model and half specimen model.

B. OBSERVATION OF LINEAR RELATIONSHIP BETWEEN EXTERNAL LOAD AND LOCAL TENSILE STRESS

The tensile stress of the element number 460 (Figure 4.3) of half specimen model which subjected to the displacement B.C. value 0.001 is 0.002475 Msi (Figure 4.9) and the tensile stress of the same element which subjected to the displacement B.C. value 0.004 is 0.0112 Msi (Figure 4.10). The ratio of tensile stress is almost the same as the ratio of displacement, the different value bases on the non-uniform of the stress around the notch region and can be accepted. When the element number 230 (Figure 4.7) of the same model, which is far from the notched region the ratio of the stresses (Figure 4.11, displacement B.C. value 0.001 and Figure 4.12, displacement B.C. value 0.004) and the ratio of the displacement are almost the same and the difference is small compare to the different value for the element in the notch region. Therefore, the linear relationship between external load and local stress can be accepted whether the element is in notch region or not. Since the element is small enough to be satisfy the uniform stress within element, then the uniformity and the linearity can be attained.

C. STATISTICAL SIZE EFFECT RESULTS DISCUSSION

Equation 2.13 and 2.14, calculated the reliability of the specimen model based on statistical size effect in two dimensional, non-homogeneous, uniaxial stress. For application in these equation, the displacement boundary condition need to be converted to the average stress along the boundary. The definition of the average stress in two dimension is:

$$\{P\} = \{ \Sigma [w_{pq} \sigma_x{}^{pq}] \} / \{ \Sigma w_{pq} \}$$

where: pq (element number) = 186, 187, 188, 189, 190, 200, 205, 210, 215, 220, 225, and 230 for half specimen model (Figure 4.7), and

pq = 163, 164, 165, 166, 167, 168, 171, 174, 177, 180, 183, 186, 189, 192, 465, 468, 471, 474, 477, 480, 483, and 486 for entire specimen (Figure 4.5 and Figure 4.13).

The values of stress in each element are shown in Table 4.1 and Table 4.2 respectively.

The statistical strength of a structure is characterized by the scale parameter β_E in equation 2.13 (same as BETAA in computer program, Appendix A). A change of the β_E value is therefore related to the strength change of the structure. The values of β_E (equation 2.14) for plate with notch, where the values of α, β, and k_c are 10, 0.1 Msi, and 0.001

0.001 respectively are shown in Table 4. 3-A. Table 4. 3-A also shows that the variation of the values of β_E which are calculated from different values of external load (PBAR) from different values of displacement boundary condition (u'). The values of β_E which calculated from half specimen model seem to be higher than β_E value from the full specimen model. The reason is that the number of elements for full specimen is less than the number of elements for half specimen model, therefore, the accuracy for full specimen model could be lower than that for half specimen model. For the purpose of reliability calculation for the structure, one can average the β_E values from one set of finite element data output from different values of load under the same boundary condition, therefore,for instance the average value of β_E is approximately 0.030. Table 4. 3-B shows the values of β_E, where the values of α, and k_c are changed to 20, and 0.0001 respectively. The β_E values are reduced but the difference of the average β_E values is not large, because of the compensation of higher α and lower k_c values. This means that the changes of α and k_c values do not affect much to the β_E value but α affects the reliability of the structure (equation 2.13). All the reliability calculation results for different values of β_E ,where the specimen models are operated in the same loading range are shown in Appendix B.

In the case of plate without notch that shown in Table 4. 3-C and Table 4. 3-D, the values of β_E from different values of displacement boundary condition are exactly the same. The reason is that the uniformity and the linearity affect the accuracy of the calculations. The value of β_E from the plate without notch (0.0439) is higher than from the plate with notch (0.028) under the same boundary condition ($u' = 0.01$), which is a reasonable result.

In addition, the results show that the material scale parameter, β is converted to β_E by the geometry of the structure and the loading boundary condition, but it does not depend on magnitude of the load. The results of the specimen model without notch confirmed that the uniform stress assumption is valid and known result can be recovered. Between results of notched specimen model we showed that β_E remains constant for different load magnitude because the uniformity and the linearity conditions are attained. As expected we confirmed the notched model is less reliability than the plain model under the same loading condition. Given available experimental data of a composite material, we can evaluate the scale parameter β and shape parameter α. Using these results we demonstrated that the procedure of analyzing the effect of a non-uniform state of stress obtained from the finite element method can be post processed by statistical reliability formulation accounted for size effect, resulting on the prediction of the reliability of the structure.

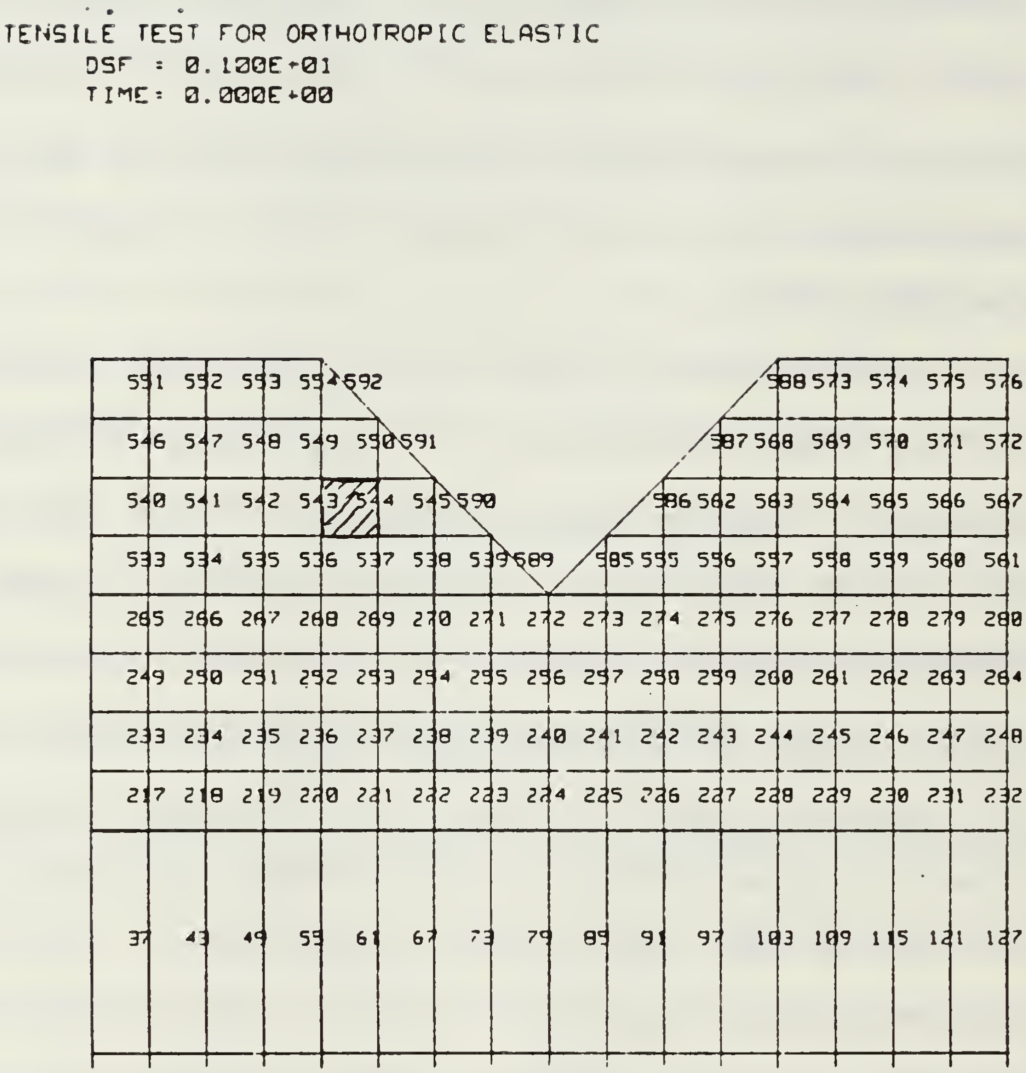


Figure 4.1 Element Numbers of Entire Specimen Model at Notch Region

```
ELEMENT NO.   L           W            SIGY          SIGZ          SIGX          SIGYZ

 2159   0.0124375   0.0124375   0.4119E-01  -0.5706E-03   0.1245E-02  -0.9971E-02
 2160   0.0124375   0.0124375   0.4100E-01  -0.9058E-03   0.1096E-02  -0.9230E-02
 2161   0.0124375   0.0124375   0.5628E-01   0.5551E-03   0.2212E-02  -0.9784E-02
 2162   0.0124375   0.0124375   0.5651E-01   0.9514E-03   0.2388E-02  -0.1059E-01
 2163   0.0124375   0.0124375   0.3714E-01  -0.1403E-03   0.1295E-02  -0.1056E-01
 2164   0.0124375   0.0124375   0.3691E-01  -0.5369E-03   0.1118E-02  -0.9745E-02
 2165   0.0124375   0.0124375   0.5245E-01   0.1090E-02   0.2307E-02  -0.1032E-01
 2166   0.0124375   0.0124375   0.5279E-01   0.1638E-02   0.2554E-02  -0.1117E-01
 2167   0.0124375   0.0124375   0.3218E-01   0.4778E-03   0.1391E-02  -0.1109E-01
 2168   0.0124375   0.0124375   0.3183E-01  -0.7994E-04   0.1144E-02  -0.1022E-01
 2169   0.0124375   0.0124375   0.4644E-01   0.1767E-02   0.2395E-02  -0.1072E-01
 2170   0.0124375   0.0124375   0.4692E-01   0.2512E-02   0.2722E-02  -0.1159E-01
 2171   0.0124375   0.0124375   0.2614E-01   0.1346E-02   0.1551E-02  -0.1143E-01
 2172   0.0124375   0.0124375   0.2566E-01   0.6011E-03   0.1222E-02  -0.1055E-01
 2173   0.0124375   0.0124375   0.3663E-01   0.2621E-02   0.2418E-02  -0.1070E-01
 2174   0.0124375   0.0124375   0.3738E-01   0.3707E-02   0.2890E-02  -0.1145E-01
 2175   0.0124375   0.0124375   0.1933E-01   0.2703E-02   0.1874E-02  -0.1110E-01
 2176   0.0124375   0.0124375   0.1857E-01   0.1616E-02   0.1401E-02  -0.1034E-01
 2177   0.0124375   0.0124375   0.2023E-01   0.3863E-02   0.2362E-02  -0.9772E-02
 2178   0.0124375   0.0124375   0.2161E-01   0.5761E-02   0.3176E-02  -0.1026E-01
 2179   0.0124375   0.0124375   0.1018E-01   0.5151E-02   0.2536E-02  -0.9374E-02
 2180   0.0124375   0.0124375   0.8793E-02   0.3253E-02   0.1721E-02  -0.8887E-02
 2181   0.0124375   0.0124375   0.3233E-01   0.1547E-03   0.1193E-02  -0.5810E-02
 2182   0.0124375   0.0124375   0.3255E-01   0.4673E-03   0.1328E-02  -0.6219E-02
 2183   0.0124375   0.0124375   0.2279E-01  -0.8192E-04   0.7775E-03  -0.6112E-02
 2184   0.0124375   0.0124375   0.2257E-01  -0.3946E-03   0.6416E-03  -0.5701E-02
 2185   0.0124375   0.0124375   0.2776E-01   0.4538E-03   0.1160E-02  -0.5691E-02
 2186   0.0124375   0.0124375   0.2803E-01   0.8321E-03   0.1324E-02  -0.6088E-02
 2187   0.0124375   0.0124375   0.1858E-01   0.3016E-03   0.7915E-03  -0.5950E-02
 2188   0.0124375   0.0124375   0.1832E-01  -0.7685E-04   0.6273E-03  -0.5552E-02
 2189   0.0124375   0.0124375   0.2249E-01   0.8205E-03   0.1130E-02  -0.5371E-02
 2190   0.0124375   0.0124375   0.2279E-01   0.1246E-02   0.1314E-02  -0.5735E-02
 2191   0.0124375   0.0124375   0.1414E-01   0.7615E-03   0.8265E-03  -0.5573E-02
 2192   0.0124375   0.0124375   0.1384E-01   0.3359E-03   0.6423E-03  -0.5207E-02
 2193   0.0124375   0.0124375   0.1646E-01   0.1234E-02   0.1091E-02  -0.4748E-02
 2194   0.0124375   0.0124375   0.1681E-01   0.1719E-02   0.1300E-02  -0.5065E-02
 2195   0.0124375   0.0124375   0.9306E-02   0.1300E-02   0.8766E-03  -0.4867E-02
 2196   0.0124375   0.0124375   0.8951E-02   0.8155E-03   0.6674E-03  -0.4549E-02
 2197   0.0124375   0.0124375   0.1006E-01   0.1590E-02   0.1010E-02  -0.3568E-02
 2198   0.0124375   0.0124375   0.1014E-01   0.1705E-02   0.1062E-02  -0.3853E-02
 2199   0.0124375   0.0124375   0.3424E-02   0.1326E-02   0.6825E-03  -0.3863E-02
 2200   0.0124375   0.0124375   0.3338E-02   0.1211E-02   0.6303E-03  -0.3578E-02
 2201   0.0124375   0.0124375   0.1624E-01   0.7671E-04   0.5890E-03  -0.1751E-02
 2202   0.0124375   0.0124375   0.1645E-01   0.3610E-03   0.7120E-03  -0.2152E-02
 2203   0.0124375   0.0124375   0.6959E-02  -0.1739E-03   0.1756E-03  -0.2043E-02
 2204   0.0124375   0.0124375   0.6748E-02  -0.4593E-03   0.5263E-04  -0.1640E-02
 2205   0.0124375   0.0124375   0.1216E-01   0.2959E-03   0.5387E-03  -0.1579E-02
 2206   0.0124375   0.0124375   0.1231E-01   0.4849E-03   0.6214E-03  -0.1962E-02
 2207   0.0124375   0.0124375   0.3268E-02  -0.2460E-04   0.1109E-03  -0.1912E-02
 2208   0.0124375   0.0124375   0.3126E-02  -0.2137E-03   0.2817E-04  -0.1528E-02
 2209   0.0124375   0.0124375   0.8107E-02   0.4039E-03   0.4432E-03  -0.1176E-02
 2210   0.0124375   0.0124375   0.8267E-02   0.6147E-03   0.5351E-03  -0.1511E-02
 2211   0.0124375   0.0124375   0.3654E-03   0.1697E-03   0.8881E-04  -0.1449E-02
 2212   0.0124375   0.0124375   0.2044E-03  -0.4109E-04  -0.3109E-05  -0.1113E-02
 2213   0.0124375   0.0124375   0.4171E-02   0.4780E-03   0.3357E-03  -0.4559E-03
 2214   0.0124375   0.0124375   0.4174E-02   0.4741E-03   0.3357E-03  -0.6822E-03
 2215   0.0124375   0.0124375  -0.1156E-02   0.1725E-03   0.3456E-04  -0.7273E-03
 2216   0.0124375   0.0124375  -0.1159E-02   0.1764E-03   0.3449E-04  -0.5003E-03
 2217   0.0124375   0.0124375   0.1776E+00   0.1479E-01   0.1263E-01   0.2630E-01
 2218   0.0124375   0.0124375   0.1755E+00   0.1005E-01   0.1047E-01   0.2095E-01
```

Figure 4.2 Stress Distribution Values of Entire Specimen Model Based on 4-Point Integration, where u' = 0.01", at Notch Region

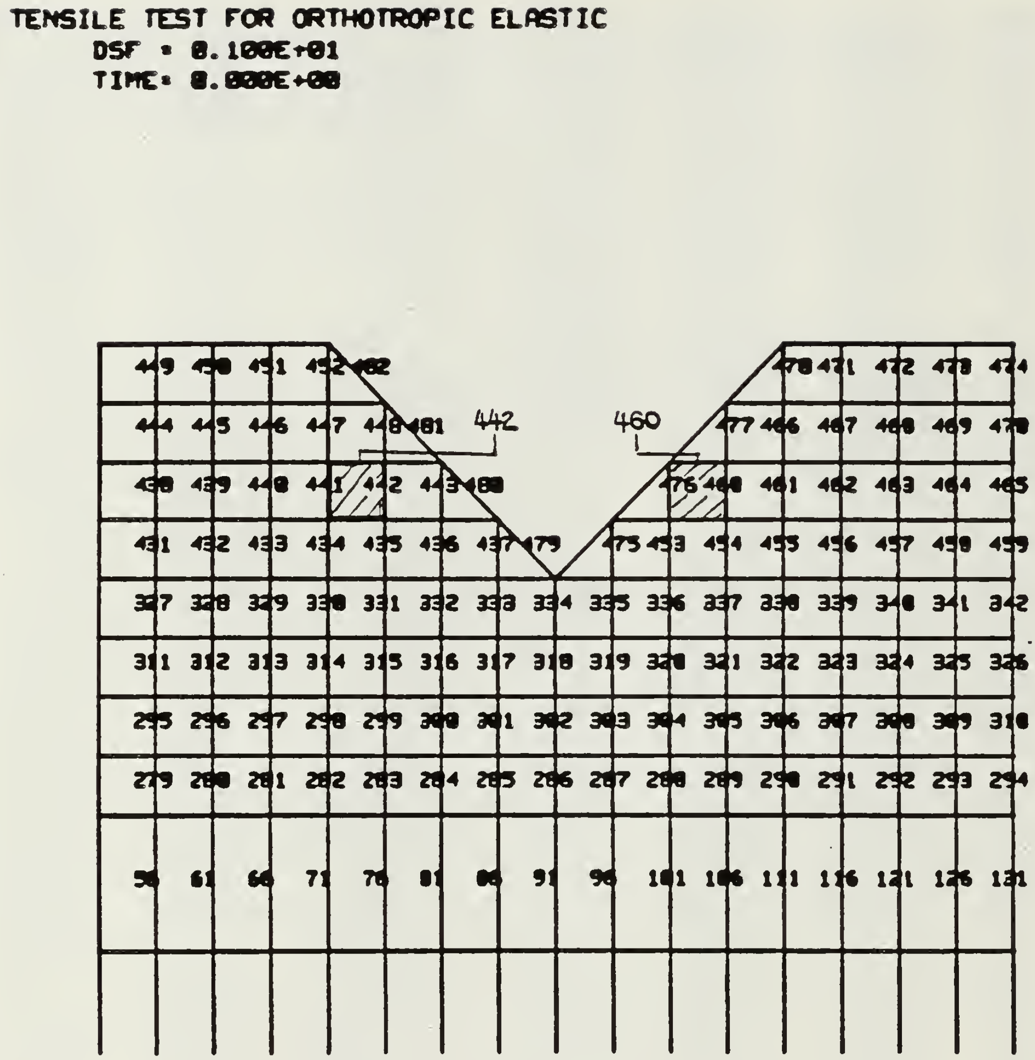


Figure 4.3 Element Numbers of Half Specimen Model at Notch Region

```
ELEMENT NO.   L            W            SIGY          SIGZ          SIGX          SIGYZ
  1739     0.0124375    0.0124375    0.6298E-01   -0.1540E-03    0.2366E-02   -0.1873E-01
  1740     0.0124375    0.0124375    0.6294E-01   -0.7335E-03    0.2069E-02   -0.1602E-01
  1741     0.0124375    0.0124375    0.1480E+00    0.5320E-02    0.7472E-02   -0.1782E-01
  1742     0.0124375    0.0124375    0.1480E+00    0.6275E-02    0.7959E-02   -0.2154E-01
  1743     0.0124375    0.0124375    0.5362E-01    0.9165E-03    0.2633E-02   -0.2310E-01
  1744     0.0124375    0.0124375    0.5360E-01   -0.3309E-04    0.2143E-02   -0.1916E-01
  1745     0.0124375    0.0124375    0.1756E+00    0.1007E-01    0.1048E-01   -0.2097E-01
  1746     0.0124375    0.0124375    0.1778E+00    0.1441E-01    0.1265E-01   -0.2633E-01
  1747     0.0124375    0.0124375    0.4032E-01    0.7089E-02    0.4915E-02   -0.2760E-01
  1748     0.0124375    0.0124375    0.3786E-01    0.2344E-02    0.2729E-02   -0.2179E-01
  1749     0.0124375    0.0124375    0.5889E-01    0.1736E-03    0.2135E-02   -0.9230E-02
  1750     0.0124375    0.0124375    0.5905E-01    0.4630E-03    0.2265E-02   -0.9965E-02
  1751     0.0124375    0.0124375    0.4126E-01   -0.5408E-03    0.1260E-02   -0.9960E-02
  1752     0.0124375    0.0124375    0.4110E-01   -0.8302E-03    0.1130E-02   -0.9218E-02
  1753     0.0124375    0.0124375    0.5036E-01    0.5683E-03    0.2720E-02   -0.9794E-02
  1754     0.0124375    0.0124375    0.5658E-01    0.9620E-03    0.2396E-02   -0.1060E-01
  1755     0.0124375    0.0124375    0.3720E-01   -0.1306E-03    0.1302E-02   -0.1057E-01
  1756     0.0124375    0.0124375    0.3697E-01   -0.5245E-03    0.1126E-02   -0.9758E-02
  1757     0.0124375    0.0124375    0.5250E-01    0.1048E-02    0.2313E-02   -0.1034E-01
  1758     0.0124375    0.0124375    0.5284E-01    0.1546E-02    0.2560E-02   -0.1119E-01
  1759     0.0124375    0.0124375    0.3223E-01    0.4858E-03    0.1397E-02   -0.1111E-01
  1760     0.0124375    0.0124375    0.3189E-01   -0.7167E-04    0.1150E-02   -0.1025E-01
  1761     0.0124375    0.0124375    0.4648E-01    0.1775E-02    0.2400E-02   -0.1075E-01
  1762     0.0124375    0.0124375    0.4696E-01    0.2522E-02    0.2728E-02   -0.1161E-01
  1763     0.0124375    0.0124375    0.2619E-01    0.1356E-02    0.1557E-02   -0.1145E-01
  1764     0.0124375    0.0124375    0.2570E-01    0.6094E-03    0.1228E-02   -0.1058E-01
  1765     0.0124375    0.0124375    0.3667E-01    0.2633E-02    0.2424E-02   -0.1073E-01
  1766     0.0124375    0.0124375    0.3742E-01    0.3722E-02    0.2898E-02   -0.1148E-01
  1767     0.0124375    0.0124375    0.1937E-01    0.2717E-02    0.1882E-02   -0.1113E-01
  1768     0.0124375    0.0124375    0.1861E-01    0.1028E-02    0.1407E-02   -0.1036E-01
  1769     0.0124375    0.0124375    0.2026E-01    0.3891E-02    0.2371E-02   -0.9800E-02
  1770     0.0124375    0.0124375    0.2165E-01    0.5794E-02    0.3188E-02   -0.1028E-01
  1771     0.0124375    0.0124375    0.1022E-01    0.5175E-02    0.2548E-02   -0.9400E-02
  1772     0.0124375    0.0124375    0.8822E-02    0.3270E-02    0.1730E-02   -0.8913E-02
  1773     0.0124375    0.0124375    0.3237E-01    0.2560E-03    0.1234E-02   -0.5794E-02
  1774     0.0124375    0.0124375    0.3255E-01    0.5321E-03    0.1355E-02   -0.6211E-02
  1775     0.0124375    0.0124375    0.2259E-01   -0.2913E-04    0.7921E-03   -0.6128E-02
  1776     0.0124375    0.0124375    0.2240E-01   -0.3053E-03    0.6717E-03   -0.5708E-02
  1777     0.0124375    0.0124375    0.2781E-01    0.5002E-03    0.1181E-02   -0.5700E-02
  1778     0.0124375    0.0124375    0.2806E-01    0.8551E-03    0.1335E-02   -0.6100E-02
  1779     0.0124375    0.0124375    0.1854E-01    0.3198E-03    0.7976E-03   -0.5977E-02
  1780     0.0124375    0.0124375    0.1829E-01   -0.3528E-04    0.6434E-03   -0.5575E-02
  1781     0.0124375    0.0124375    0.2253E-01    0.8347E-03    0.1138E-02   -0.5391E-02
  1782     0.0124375    0.0124375    0.2283E-01    0.1257E-02    0.1320E-02   -0.5756E-02
  1783     0.0124375    0.0124375    0.1415E-01    0.7701E-03    0.8306E-03   -0.5597E-02
  1784     0.0124375    0.0124375    0.1385E-01    0.3490E-03    0.6479E-03   -0.5229E-02
  1785     0.0124375    0.0124375    0.1650E-01    0.1244E-02    0.1096E-02   -0.4769E-02
  1786     0.0124375    0.0124375    0.1685E-01    0.1729E-02    0.1306E-02   -0.5087E-02
  1787     0.0124375    0.0124375    0.9333E-02    0.1310E-02    0.8816E-03   -0.4890E-02
  1788     0.0124375    0.0124375    0.5977E-02    0.8244E-03    0.6722E-03   -0.4571E-02
  1789     0.0124375    0.0124375    0.1009E-01    0.1602E-02    0.1016E-02   -0.3590E-02
  1790     0.0124375    0.0124375    0.1018E-01    0.1723E-02    0.1071E-02   -0.3876E-02
  1791     0.0124375    0.0124375    0.3452E-02    0.1343E-02    0.6906E-03   -0.3884E-02
  1792     0.0124375    0.0124375    0.3362E-02    0.1222E-02    0.6361E-03   -0.3597E-02
  1793     0.0124375    0.0124375    0.1619E-01    0.1834E-03    0.6304E-03   -0.1851E-02
  1794     0.0124375    0.0124375    0.1634E-01    0.3898E-03    0.7201E-03   -0.2230E-02
  1795     0.0124375    0.0124375    0.7355E-02   -0.1169E-03    0.2125E-03   -0.2163E-02
  1796     0.0124375    0.0124375    0.7203E-02   -0.3233E-03    0.1227E-03   -0.1742E-02
  1797     0.0124375    0.0124375    0.1216E-01    0.3030E-03    0.5417E-03   -0.1633E-02
  1798     0.0124375    0.0124375    0.1230E-01    0.4901E-03    0.6235E-03   -0.2006E-02
```

Figure 4.4 Stress Distribution Values of Half Specimen Model Based on 4-Point Integration, where u' = 0.01", at Notch Region

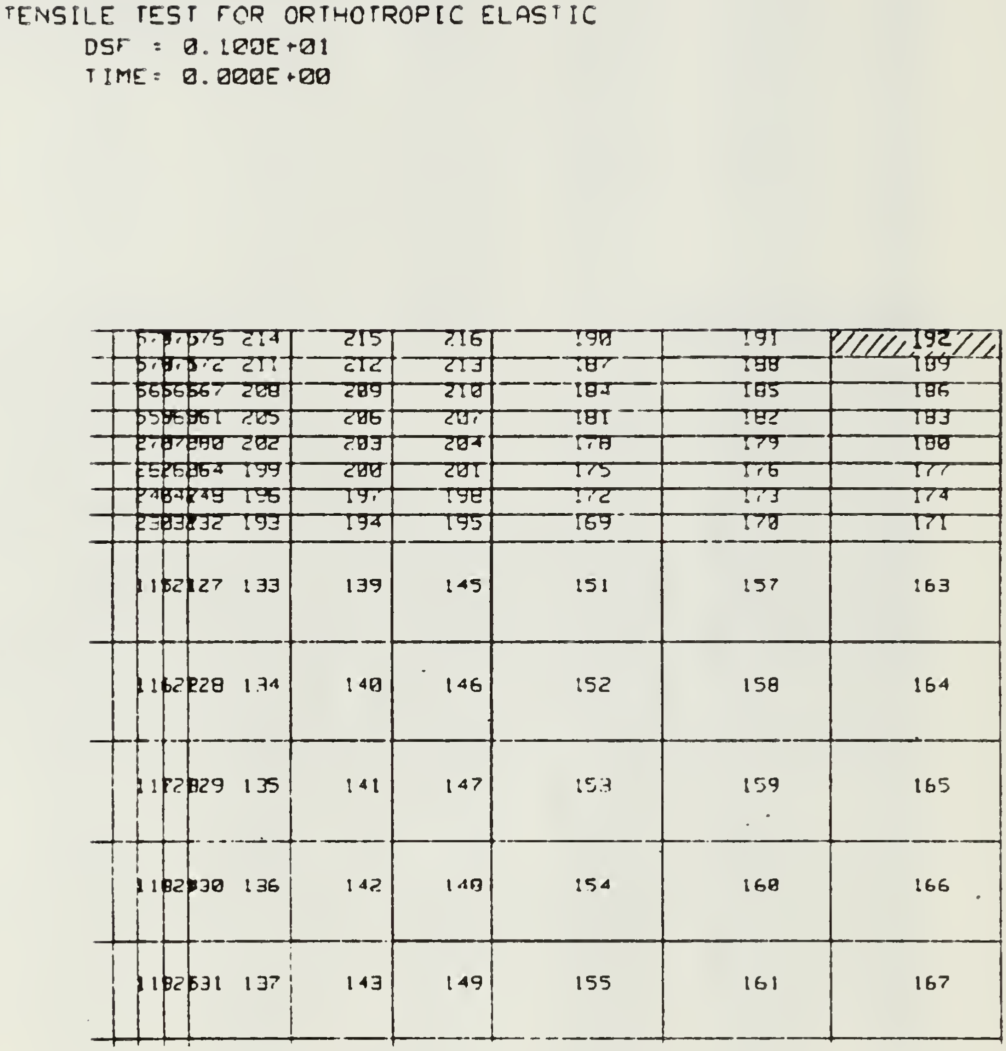


Figure 4.5 Element Numbers of Entire Specimen Model at Top-Right Boundary Region

```
ELEMENT NO.   L            W            SIGY          SIGZ          SIGX          SIGYZ

   719   0.0829167   0.0124375   0.7796E-01  -0.5755E-03   0.2409E-02   0.2635E-03
   720   0.0829167   0.0124375   0.7783E-01  -0.6099E-03   0.2395E-02   0.8656E-03
   721   0.0829167   0.0124375   0.7630E-01  -0.5905E-03   0.2357E-02   0.3802E-02
   722   0.0829167   0.0124375   0.7644E-01  -0.4555E-03   0.2413E-02   0.2669E-02
   723   0.0829167   0.0124375   0.7229E-01  -0.6902E-03   0.2178E-02   0.2687E-02
   724   0.0829167   0.0124375   0.7215E-01  -0.8252E-03   0.2123E-02   0.3823E-02
   725   0.0829167   0.0124375   0.7627E-01  -0.3990E-03   0.2428E-02   0.2116E-02
   726   0.0829167   0.0124375   0.7633E-01  -0.3416E-03   0.2452E-02   0.1372E-02
   727   0.0829167   0.0124375   0.7360E-01  -0.4958E-03   0.2298E-02   0.1379E-02
   728   0.0829167   0.0124375   0.7355E-01  -0.5531E-03   0.2274E-02   0.2124E-02
   729   0.0829167   0.0124375   0.7653E-01  -0.3056E-03   0.2473E-02   0.8389E-03
   730   0.0829167   0.0124375   0.7655E-01  -0.2916E-03   0.2478E-02   0.2574E-03
   731   0.0829167   0.0124375   0.7441E-01  -0.4121E-03   0.2358E-02   0.2588E-03
   732   0.0829167   0.0124375   0.7440E-01  -0.4261E-03   0.2352E-02   0.8410E-03
   733   0.0829167   0.0124375   0.6972E-01  -0.2645E-03   0.2263E-02   0.3477E-02
   734   0.0829167   0.0124375   0.6974E-01  -0.2795E-03   0.2255E-02   0.2380E-02
   735   0.0829167   0.0124375   0.6573E-01  -0.5061E-03   0.2028E-02   0.2384E-02
   736   0.0829167   0.0124375   0.6571E-01  -0.4911E-03   0.2037E-02   0.3484E-02
   737   0.0829167   0.0124375   0.7203E-01  -0.1675E-03   0.2376E-02   0.1857E-02
   738   0.0829167   0.0124375   0.7202E-01  -0.1986E-03   0.2362E-02   0.1192E-02
   739   0.0829167   0.0124375   0.6958E-01  -0.3361E-03   0.2225E-02   0.1190E-02
   740   0.0829167   0.0124375   0.6960E-01  -0.3049E-03   0.2239E-02   0.1856E-02
   741   0.0829167   0.0124375   0.7323E-01  -0.1445E-03   0.2425E-02   0.7159E-03
   742   0.0829167   0.0124375   0.7323E-01  -0.1542E-03   0.2421E-02   0.2253E-03
   743   0.0829167   0.0124375   0.7143E-01  -0.2557E-03   0.2319E-02   0.2246E-03
   744   0.0829167   0.0124375   0.7144E-01  -0.2460E-03   0.2324E-02   0.7157E-03
   745   0.0829167   0.0124375   0.6360E-01   0.3700E-05   0.2161E-02   0.2524E-02
   746   0.0829167   0.0124375   0.6350E-01  -0.1590E-03   0.2090E-02   0.1669E-02
   747   0.0829167   0.0124375   0.6039E-01  -0.3349E-03   0.1914E-02   0.1658E-02
   748   0.0829167   0.0124375   0.6049E-01  -0.1722E-03   0.1985E-02   0.2515E-02
   749   0.0829167   0.0124375   0.6839E-01   0.1762E-04   0.2326E-02   0.1303E-02
   750   0.0829167   0.0124375   0.6830E-01  -0.1009E-03   0.2275E-02   0.8289E-03
   751   0.0829167   0.0124375   0.6657E-01  -0.1987E-03   0.2178E-02   0.8192E-03
   752   0.0829167   0.0124375   0.6605E-01  -0.8020E-04   0.2228E-02   0.1294E-02
   753   0.0829167   0.0124375   0.7056E-01  -0.2619E-04   0.2381E-02   0.4888E-03
   754   0.0829167   0.0124375   0.7053E-01  -0.5734E-04   0.2368E-02   0.1628E-03
   755   0.0829167   0.0124375   0.6934E-01  -0.1247E-03   0.2301E-02   0.1601E-03
   756   0.0829167   0.0124375   0.6936E-01  -0.9351E-04   0.2314E-02   0.4863E-03
   757   0.0829167   0.0124375   0.5913E-01   0.1424E-03   0.2062E-02   0.1002E-02
   758   0.0829167   0.0124375   0.5893E-01  -0.1268E-03   0.1947E-02   0.5889E-03
   759   0.0829167   0.0124375   0.5743E-01  -0.2117E-03   0.1862E-02   0.5662E-03
   760   0.0829167   0.0124375   0.5763E-01   0.5757E-04   0.1977E-02   0.9800E-03
   761   0.0829167   0.0124375   0.6596E-01   0.1124E-03   0.2281E-02   0.4990E-03
   762   0.0829167   0.0124375   0.6562E-01  -0.6721E-04   0.2205E-02   0.3103E-03
   763   0.0829167   0.0124375   0.6514E-01  -0.1061E-03   0.2166E-02   0.2948E-03
   764   0.0829167   0.0124375   0.6527E-01   0.7355E-04   0.2242E-02   0.4836E-03
   765   0.0829167   0.0124375   0.6891E-01   0.2826E-04   0.2347E-02   0.1731E-03
   766   0.0829167   0.0124375   0.6888E-01  -0.1729E-04   0.2328E-02   0.7441E-04
   767   0.0829167   0.0124375   0.6852E-01  -0.3757E-04   0.2308E-02   0.7046E-04
   768   0.0829167   0.0124375   0.6855E-01   0.7889E-05   0.2327E-02   0.1692E-03
   769   0.0829167   0.0124375   0.1006E+00  -0.1858E-03   0.3337E-02  -0.6005E-03
   770   0.0829167   0.0124375   0.1002E+00  -0.7644E-03   0.3091E-02  -0.3267E-03
   771   0.0829167   0.0124375   0.1019E+00  -0.5681E-03   0.3187E-02  -0.4154E-03
   772   0.0829167   0.0124375   0.1023E+00  -0.8955E-04   0.3433E-02  -0.6889E-03
   773   0.0829167   0.0124375   0.9816E-01  -0.1115E-02   0.2883E-02   0.7519E-03
   774   0.0829167   0.0124375   0.9810E-01  -0.1192E-02   0.2850E-02   0.8125E-03
   775   0.0829167   0.0124375   0.9847E-01  -0.1171E-02   0.2871E-02   0.8006E-03
   776   0.0829167   0.0124375   0.9853E-01  -0.1094E-02   0.2904E-02   0.7400E-03
```

Figure 4.6 Stress Distribution Values of Entire Specimen Model Based on 4-Point Integration, where u' = 0.01", at Top-Right Boundary Region

TENSILE TEST FOR ORTHOTROPIC ELASTIC
DSF = 0.100E+01
TIME= 0.000E+00

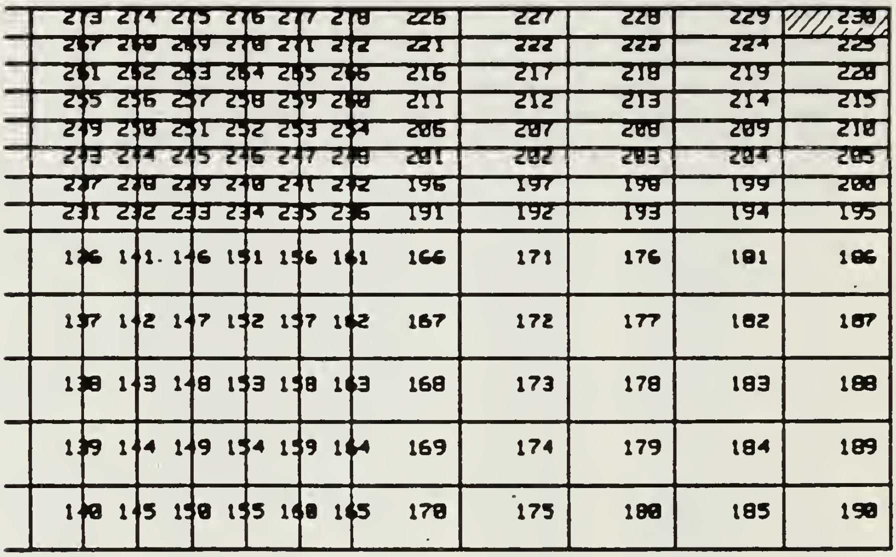


Figure 4.7 Element Numbers of Half Specimen Model at Right Boundary Region

```
ELEMENT NO.    L            W            SIGY          SIGZ          SIGX          SIGYZ

   900     0.0497500    0.0124375    0.6950E-01   -0.1052E-03    0.2314E-02    0.2849E-03
   901     0.0497500    0.0124375    0.5716E-01    0.9190E-04    0.1975E-02    0.1022E-02
   902     0.0497500    0.0124375    0.5703E-01   -0.4662E-04    0.1899E-02    0.7300E-03
   903     0.0497500    0.0124375    0.5526E-01   -0.1868E-03    0.1799E-02    0.7052E-03
   904     0.0497500    0.0124375    0.5539E-01   -0.8020E-05    0.1875E-02    0.9979E-03
   905     0.0497500    0.0124375    0.6239E-01    0.9652E-04    0.2154E-02    0.6939E-03
   906     0.0497500    0.0124375    0.6227E-01   -0.6405E-04    0.2085E-02    0.5138E-03
   907     0.0497500    0.0124375    0.6118E-01   -0.1258E-03    0.2024E-02    0.4909E-03
   908     0.0497500    0.0124375    0.6129E-01    0.3491E-04    0.2092E-02    0.6711E-03
   909     0.0497500    0.0124375    0.6589E-01    0.5036E-04    0.2254E-02    0.4500E-03
   910     0.0497500    0.0124375    0.6582E-01   -0.4539E-04    0.2213E-02    0.3378E-03
   911     0.0497500    0.0124375    0.6513E-01   -0.8394E-04    0.2174E-02    0.3240E-03
   912     0.0497500    0.0124375    0.6520E-01    0.1192E-04    0.2215E-02    0.4363E-03
   913     0.0497500    0.0124375    0.6804E-01    0.2732E-04    0.2318E-02    0.2582E-03
   914     0.0497500    0.0124375    0.6800E-01   -0.2803E-04    0.2294E-02    0.1849E-03
   915     0.0497500    0.0124375    0.6755E-01   -0.5322E-04    0.2269E-02    0.1769E-03
   916     0.0497500    0.0124375    0.6759E-01    0.2134E-05    0.2292E-02    0.2502E-03
   917     0.0497500    0.0124375    0.6906E-01    0.6354E-05    0.2344E-02    0.9957E-04
   918     0.0497500    0.0124375    0.6905E-01   -0.1120E-04    0.2336E-02    0.4345E-04
   919     0.0497500    0.0124375    0.6871E-01   -0.3050E-04    0.2317E-02    0.4091E-04
   920     0.0497500    0.0124375    0.6872E-01   -0.1294E-04    0.2324E-02    0.9704E-04
   921     0.0248750    0.0124375    0.1014E+00   -0.4722E-04    0.3416E-02   -0.9656E-03
   922     0.0248750    0.0124375    0.1011E+00   -0.4464E-03    0.3247E-02   -0.8075E-03
   923     0.0248750    0.0124375    0.1030E+00   -0.3350E-03    0.3358E-02   -0.9293E-03
   924     0.0248750    0.0124375    0.1033E+00    0.6417E-04    0.3527E-02   -0.1087E-02
   925     0.0248750    0.0124375    0.1002E+00   -0.7058E-03    0.3116E-02   -0.1406E-03
   926     0.0248750    0.0124375    0.1001E+00   -0.9020E-03    0.3033E-02   -0.3849E-04
   927     0.0248750    0.0124375    0.1014E+00   -0.9302E-03    0.3104E-02   -0.9871E-04
   928     0.0248750    0.0124375    0.1015E+00   -0.6340E-03    0.3187E-02   -0.2007E-03
   929     0.0248750    0.0124375    0.9891E-01   -0.1065E-02    0.2928E-02    0.5060E-03
   930     0.0248750    0.0124375    0.9896E-01   -0.1136E-02    0.2898E-02    0.5562E-03
   931     0.0248750    0.0124375    0.9948E-01   -0.1101E-02    0.2933E-02    0.5342E-03
   932     0.0248750    0.0124375    0.9953E-01   -0.1030E-02    0.2963E-02    0.4840E-03
   933     0.0248750    0.0124375    0.9750E-01   -0.1239E-02    0.2811E-02    0.9728E-03
   934     0.0248750    0.0124375    0.9750E-01   -0.1237E-02    0.2812E-02    0.9797E-03
   935     0.0248750    0.0124375    0.9757E-01   -0.1233E-02    0.2816E-02    0.9790E-03
   936     0.0248750    0.0124375    0.9757E-01   -0.1235E-02    0.2815E-02    0.9732E-03
   937     0.0248750    0.0124375    0.9611E-01   -0.1301E-02    0.2740E-02    0.1279E-02
   938     0.0248750    0.0124375    0.9615E-01   -0.1258E-02    0.2758E-02    0.1249E-02
   939     0.0248750    0.0124375    0.9578E-01   -0.1279E-02    0.2737E-02    0.1262E-02
   940     0.0248750    0.0124375    0.9575E-01   -0.1322E-02    0.2719E-02    0.1292E-02
   941     0.0248750    0.0124375    0.9461E-01   -0.1298E-02    0.2697E-02    0.1449E-02
   942     0.0248750    0.0124375    0.9485E-01   -0.1234E-02    0.2724E-02    0.1392E-02
   943     0.0248750    0.0124375    0.9415E-01   -0.1274E-02    0.2683E-02    0.1411E-02
   944     0.0248750    0.0124375    0.9410E-01   -0.1338E-02    0.2656E-02    0.1469E-02
   945     0.0248750    0.0124375    0.1043E+00   -0.5267E-03    0.3286E-02   -0.1590E-04
   946     0.0248750    0.0124375    0.1041E+00   -0.8917E-03    0.3174E-02    0.1676E-03
   947     0.0248750    0.0124375    0.1064E+00   -0.7625E-03    0.3303E-02    0.8291E-04
   948     0.0248750    0.0124375    0.1066E+00   -0.4975E-03    0.3415E-02   -0.1004E-03
   949     0.0248750    0.0124375    0.1019E+00   -0.1139E-02    0.3002E-02    0.9429E-03
   950     0.0248750    0.0124375    0.1019E+00   -0.1211E-02    0.2972E-02    0.1021E-02
   951     0.0248750    0.0124375    0.1028E+00   -0.1156E-02    0.3026E-02    0.9971E-03
   952     0.0248750    0.0124375    0.1029E+00   -0.1085E-02    0.3056E-02    0.9194E-03
   953     0.0248750    0.0124375    0.9947E-01   -0.1362E-02    0.2831E-02    0.1602E-02
   954     0.0248750    0.0124375    0.9950E-01   -0.1327E-02    0.2846E-02    0.1598E-02
   955     0.0248750    0.0124375    0.9945E-01   -0.1330E-02    0.2843E-02    0.1608E-02
   956     0.0248750    0.0124375    0.9942E-01   -0.1365E-02    0.2828E-02    0.1612E-02
   957     0.0248750    0.0124375    0.9718E-01   -0.1420E-02    0.2730E-02    0.2007E-02
   958     0.0248750    0.0124375    0.9724E-01   -0.1336E-02    0.2766E-02    0.1945E-02
```

Figure 4.8 Stress Distribution Values of Half Specimen Model Based on 4-Point Integration, where u' = 0.01", at Right Boundary Region

```
ELEMENT NO.   L            W            SIGY         SIGZ          SIGX          SIGYZ
   419    0.0995000    0.0248750    0.5842E-02  -0.3368E-04    0.2185E-03  -0.2320E-03
   420    0.0995000    0.0248750    0.6010E-02  -0.4364E-04    0.2067E-03  -0.3336E-03
   421    0.0995000    0.0248750    0.5951E-02  -0.7836E-05    0.2325E-03  -0.1829E-04
   422    0.0995000    0.0248750    0.5863E-02  -0.8937E-05    0.2291E-03  -0.5748E-04
   423    0.0995000    0.0248750    0.5680E-02  -0.1110E-04    0.2220E-03  -0.1039E-03
   424    0.0995000    0.0248750    0.6385E-02  -0.1436E-04    0.2107E-03  -0.1623E-03
   425    0.0995000    0.0248750    0.5955E-02  -0.1867E-04    0.1944E-03  -0.2378E-03
   426    0.0995000    0.0248750    0.5628E-02  -0.1687E-05    0.2308E-03  -0.6534E-05
   427    0.0995000    0.0248750    0.5720E-02  -0.1767E-05    0.2271E-03  -0.2041E-04
   428    0.0995000    0.0248750    0.6488E-02  -0.2515E-05    0.2189E-03  -0.3737E-04
   429    0.0995000    0.0248750    0.6102E-02  -0.3070E-05    0.2056E-03  -0.5883E-04
   430    0.0995000    0.0248750    0.5515E-02  -0.3952E-05    0.1854E-03  -0.8726E-04
   431    0.0248750    0.0248750    0.8104E-02  -0.8323E-04    0.2422E-03  -0.1032E-02
   432    0.0248750    0.0248750    0.8292E-02  -0.5165E-04    0.2614E-03  -0.1124E-02
   433    0.0248750    0.0248750    0.8514E-02  -0.3277E-05    0.2885E-03  -0.1237E-02
   434    0.0248750    0.0248750    0.8762E-02   0.5623E-04    0.3211E-03  -0.1383E-02
   435    0.0248750    0.0248750    0.9020E-02   0.2059E-03    0.3904E-03  -0.1630E-02
   436    0.0248750    0.0248750    0.9461E-02   0.2251E-03    0.4145E-03  -0.2108E-02
   437    0.0248750    0.0248750    0.1182E-01   0.8839E-03    0.7614E-03  -0.2805E-02
   438    0.0248750    0.0248750    0.4926E-02  -0.8854E-05    0.1642E-03  -0.9708E-03
   439    0.0248750    0.0248750    0.4579E-02   0.3261E-04    0.1692E-03  -0.1038E-02
   440    0.0248750    0.0248750    0.4103E-02   0.9364E-04    0.1776E-03  -0.1108E-02
   441    0.0248750    0.0248750    0.3428E-02   0.1761E-03    0.1890E-03  -0.1174E-02
   442    0.0248750    0.0248750    0.2377E-02   0.2666E-03    0.1886E-03  -0.1131E-02
   443    0.0248750    0.0248750    0.2482E-03   0.5129E-03    0.2149E-03  -0.9561E-03
   444    0.0248750    0.0248750    0.2567E-02   0.1626E-04    0.9471E-04  -0.6179E-03
   445    0.0248750    0.0248750    0.2112E-02   0.5034E-04    0.9217E-04  -0.5942E-03
   446    0.0248750    0.0248750    0.1586E-02   0.9117E-04    0.9064E-04  -0.5385E-03
   447    0.0248750    0.0248750    0.9820E-03   0.1439E-03    0.9121E-04  -0.4389E-03
   448    0.0248750    0.0248750    0.4668E-03   0.1437E-03    0.7359E-04  -0.3152E-03
   449    0.0248750    0.0248750    0.9175E-03   0.8305E-05    0.3452E-04  -0.2020E-03
   450    0.0248750    0.0248750    0.5372E-03   0.1334E-04    0.2364E-04  -0.1793E-03
   451    0.0248750    0.0248750    0.2305E-03   0.2999E-04    0.1989E-04  -0.1358E-03
   452    0.0248750    0.0248750    0.5876E-04   0.3977E-04    0.1727E-04  -0.6723E-04
   453    0.0248750    0.0248750    0.1182E-01   0.8834E-03    0.7611E-03   0.2805E-02
   454    0.0248750    0.0248750    0.9460E-02   0.2249E-03    0.4144E-03   0.2107E-02
   455    0.0248750    0.0248750    0.9019E-02   0.2057E-03    0.3903E-03   0.1630E-02
   456    0.0248750    0.0248750    0.8761E-02   0.5623E-04    0.3211E-03   0.1382E-02
   457    0.0248750    0.0248750    0.8513E-02  -0.3259E-05    0.2885E-03   0.1237E-02
   458    0.0248750    0.0248750    0.8292E-02  -0.5159E-04    0.2614E-03   0.1123E-02
   459    0.0248750    0.0248750    0.8104E-02  -0.8314E-04    0.2423E-03   0.1032E-02
   460    0.0248750    0.0248750    0.2475E-03   0.5126E-03    0.2147E-03   0.9556E-03
   461    0.0248750    0.0248750    0.2377E-02   0.2654E-03    0.1886E-03   0.1131E-02
   462    0.0248750    0.0248750    0.3428E-02   0.1761E-03    0.1879E-03   0.1174E-02
   463    0.0248750    0.0248750    0.4102E-02   0.9364E-04    0.1776E-03   0.1108E-02
   464    0.0248750    0.0248750    0.4579E-02   0.3265E-04    0.1692E-03   0.1038E-02
   465    0.0248750    0.0248750    0.4925E-02  -0.8794E-05    0.1642E-03   0.9704E-03
   466    0.0248750    0.0248750    0.4662E-03   0.1435E-03    0.7349E-04   0.3148E-03
   467    0.0248750    0.0248750    0.9812E-03   0.1438E-03    0.9116E-04   0.4385E-03
   468    0.0248750    0.0248750    0.1545E-02   0.9117E-04    0.9060E-04   0.5380E-03
   469    0.0248750    0.0248750    0.2112E-02   0.5037E-04    0.9214E-04   0.5937E-03
   470    0.0248750    0.0248750    0.2566E-02   0.1629E-04    0.9469E-04   0.6175E-03
   471    0.0248750    0.0248750    0.3637E-04   0.3972E-04    0.1724E-04   0.6703E-04
   472    0.0248750    0.0248750    0.2297E-03   0.3000E-04    0.1967E-04   0.1356E-03
   473    0.0248750    0.0248750    0.5360E-03   0.1334E-04    0.2360E-04   0.1791E-03
   474    0.0248750    0.0248750    0.9159E-03   0.8315E-05    0.3447E-04   0.2018E-03
   475    0.0248750    0.0248750    0.2071E-01   0.2029E-02    0.1523E-02   0.3148E-02
   476    0.0248750    0.0248750   -0.6953E-02   0.4412E-03   -0.2734E-04   0.1294E-03
   477    0.0248750    0.0248750    0.8210E-03   0.1419E-03    0.8458E-04   0.7377E-05
   478    0.0248750    0.0248750   -0.1452E-03   0.2641E-04    0.5620E-05  -0.2835E-04
```

Figure 4.9 Stress Distribution Values of Half Specimen Model Based ON 1-Point Integration, where u' = 0.001", at Notch Region

```
ELEMENT NO.   L            W            SIGY          SIGZ          SIGX          SIGYZ

  419     0.0995000    0.0248750    0.2735E-01   -0.1323E-03    0.8747E-03   -0.9143E-03
  420     0.0995000    0.0248750    0.2643E-01   -0.1715E-03    0.8281E-03   -0.1320E-02
  421     0.0995000    0.0248750    0.2778E-01   -0.3096E-04    0.9292E-03   -0.7256E-04
  422     0.0995000    0.0248750    0.2743E-01   -0.3523E-04    0.9157E-03   -0.2279E-03
  423     0.0995000    0.0248750    0.2670E-01   -0.4361E-04    0.8878E-03   -0.4113E-03
  424     0.0995000    0.0248750    0.2553E-01   -0.5629E-04    0.8432E-03   -0.6418E-03
  425     0.0995000    0.0248750    0.2382E-01   -0.7315E-04    0.7787E-03   -0.9396E-03
  426     0.0995000    0.0248750    0.2728E-01   -0.6612E-05    0.9222E-03   -0.2597E-04
  427     0.0995000    0.0248750    0.2685E-01   -0.6911E-05    0.9075E-03   -0.8102E-04
  428     0.0995000    0.0248750    0.2593E-01   -0.9814E-05    0.8752E-03   -0.1480E-03
  429     0.0995000    0.0248750    0.2441E-01   -0.1195E-04    0.8226E-03   -0.2323E-03
  430     0.0995000    0.0248750    0.2208E-01   -0.1539E-04    0.7425E-03   -0.3436E-03
  431     0.0248750    0.0248750    0.3238E-01   -0.3445E-03    0.9727E-03   -0.4079E-02
  432     0.0248750    0.0248750    0.3313E-01   -0.2229E-03    0.1050E-02   -0.4438E-02
  433     0.0248750    0.0248750    0.3402E-01   -0.3453E-04    0.1159E-02   -0.4880E-02
  434     0.0248750    0.0248750    0.3501E-01    0.1994E-03    0.1292E-02   -0.5452E-02
  435     0.0248750    0.0248750    0.3605E-01    0.7913E-03    0.1575E-02   -0.6425E-02
  436     0.0248750    0.0248750    0.3787E-01    0.9833E-03    0.1697E-02   -0.8306E-02
  437     0.0248750    0.0248750    0.4708E-01    0.3471E-02    0.3098E-02   -0.1094E-01
  438     0.0248750    0.0248750    0.1970E-01   -0.5211E-04    0.6587E-03   -0.3852E-02
  439     0.0248750    0.0248750    0.1832E-01    0.1083E-03    0.6787E-03   -0.4122E-02
  440     0.0248750    0.0248750    0.1643E-01    0.3467E-03    0.7127E-03   -0.4403E-02
  441     0.0248750    0.0248750    0.1375E-01    0.6743E-03    0.7564E-03   -0.4671E-02
  442     0.0248750    0.0248750    0.9544E-02    0.1038E-02    0.7629E-03   -0.4517E-02
  443     0.0248750    0.0248750    0.1115E-02    0.2042E-02    0.8755E-03   -0.3867E-02
  444     0.0248750    0.0248750    0.1034E-01    0.6017E-04    0.3806E-03   -0.2461E-02
  445     0.0248750    0.0248750    0.8532E-02    0.1845E-03    0.3697E-03   -0.2374E-02
  446     0.0248750    0.0248750    0.6444E-02    0.3475E-03    0.3641E-03   -0.2161E-02
  447     0.0248750    0.0248750    0.4047E-02    0.5600E-03    0.3672E-03   -0.1778E-02
  448     0.0248750    0.0248750    0.1974E-02    0.5823E-03    0.3046E-03   -0.1299E-02
  449     0.0248750    0.0248750    0.3787E-02    0.2848E-04    0.1413E-03   -0.8083E-03
  450     0.0248750    0.0248750    0.2247E-02    0.4845E-04    0.9709E-04   -0.7241E-03
  451     0.0248750    0.0248750    0.9889E-03    0.1126E-03    0.7995E-04   -0.5579E-03
  452     0.0248750    0.0248750    0.1826E-03    0.1607E-03    0.7126E-04   -0.2868E-03
  453     0.0248750    0.0248750    0.4708E-01    0.3470E-02    0.3097E-02    0.1094E-01
  454     0.0248750    0.0248750    0.3787E-01    0.9824E-03    0.1697E-02    0.8304E-02
  455     0.0248750    0.0248750    0.3605E-01    0.7907E-03    0.1575E-02    0.6424E-02
  456     0.0248750    0.0248750    0.3501E-01    0.1993E-03    0.1292E-02    0.5450E-02
  457     0.0248750    0.0248750    0.3401E-01   -0.3446E-04    0.1159E-02    0.4879E-02
  458     0.0248750    0.0248750    0.3313E-01   -0.2226E-03    0.1050E-02    0.4437E-02
  459     0.0248750    0.0248750    0.3238E-01   -0.3441E-03    0.9728E-03    0.4078E-02
  460     0.0248750    0.0248750    0.1112E-02    0.2041E-02    0.8748E-03    0.3865E-02
  461     0.0248750    0.0248750    0.9561E-02    0.1038E-02    0.7626E-03    0.4515E-02
  462     0.0248750    0.0248750    0.1374E-01    0.6740E-03    0.7562E-03    0.4670E-02
  463     0.0248750    0.0248750    0.1642E-01    0.3467E-03    0.7126E-03    0.4402E-02
  464     0.0248750    0.0248750    0.1832E-01    0.1085E-03    0.6786E-03    0.4121E-02
  465     0.0248750    0.0248750    0.1970E-01   -0.5144E-04    0.6588E-03    0.3851E-02
  466     0.0248750    0.0248750    0.1972E-02    0.5815E-03    0.3043E-03    0.1297E-02
  467     0.0248750    0.0248750    0.4043E-02    0.5599E-03    0.3670E-03    0.1776E-02
  468     0.0248750    0.0248750    0.6440E-02    0.3475E-03    0.3639E-03    0.2159E-02
  469     0.0248750    0.0248750    0.8528E-02    0.1847E-03    0.3696E-03    0.2372E-02
  470     0.0248750    0.0248750    0.1033E-01    0.6031E-04    0.3805E-03    0.2460E-02
  471     0.0248750    0.0248750    0.1811E-03    0.1605E-03    0.7113E-04    0.2861E-03
  472     0.0248750    0.0248750    0.9859E-03    0.1127E-03    0.7988E-04    0.5571E-03
  473     0.0248750    0.0248750    0.2242E-02    0.4847E-04    0.9694E-04    0.7233E-03
  474     0.0248750    0.0248750    0.3730E-02    0.2853E-04    0.1411E-03    0.8076E-03
  475     0.0248750    0.0248750    0.9216E-01    0.7963E-02    0.6125E-02    0.1231E-01
  476     0.0248750    0.0248750   -0.2365E-01    0.1891E-02   -0.6077E-04    0.8111E-03
  477     0.0248750    0.0248750    0.3350E-02    0.6053E-03    0.3560E-03    0.7454E-04
  478     0.0248750    0.0248750   -0.5950E-03    0.1196E-03    0.2736E-04   -0.9671E-04
```

Figure 4.10 Stress Distribution Values of Half Specimen Model Based on 1-Point Integration, where u' = 0.004", at Notch Region

ELEMENT NO.	L	W	SIGY	SIGZ	SIGX	SIGYZ
179	0.0995000	0.0570000	0.9564E-02	-0.1322E-03	0.2713E-03	0.3107E-05
180	0.0995000	0.0570000	0.9578E-02	-0.1319E-03	0.2720E-03	0.5283E-06
181	0.0995000	0.0570000	0.9106E-02	-0.1156E-03	0.2621E-03	0.4696E-04
182	0.0995000	0.0570000	0.9379E-02	-0.1287E-03	0.2655E-03	0.2226E-04
183	0.0995000	0.0570000	0.9595E-02	-0.1337E-03	0.2688E-03	0.8766E-05
184	0.0995000	0.0570000	0.9558E-02	-0.1354E-03	0.2699E-03	0.2949E-05
185	0.0995000	0.0570000	0.9576E-02	-0.1358E-03	0.2703E-03	0.6643E-06
186	0.0995000	0.0570000	0.9071E-02	-0.1135E-03	0.2621E-03	0.1615E-04
187	0.0995000	0.0570000	0.9355E-02	-0.1273E-03	0.2663E-03	0.7846E-05
188	0.0995000	0.0570000	0.9496E-02	-0.1337E-03	0.2684E-03	0.3241E-05
189	0.0995000	0.0570000	0.9554E-02	-0.1362E-03	0.2694E-03	0.1156E-05
190	0.0995000	0.0570000	0.9575E-02	-0.1370E-03	0.2698E-03	0.2766E-06
191	0.0995000	0.0248750	0.9250E-02	-0.1331E-03	0.2604E-03	0.1649E-03
192	0.0995000	0.0248750	0.9037E-02	-0.1215E-03	0.2578E-03	0.1475E-03
193	0.0995000	0.0248750	0.8891E-02	-0.1105E-03	0.2572E-03	0.1133E-03
194	0.0995000	0.0248750	0.8801E-02	-0.1025E-03	0.2574E-03	0.7049E-04
195	0.0995000	0.0248750	0.8758E-02	-0.9830E-04	0.2576E-03	0.2386E-04
196	0.0995000	0.0248750	0.9000E-02	-0.1285E-03	0.2537E-03	0.2313E-03
197	0.0995000	0.0248750	0.8766E-02	-0.1121E-03	0.2524E-03	0.1925E-03
198	0.0995000	0.0248750	0.8617E-02	-0.9876E-04	0.2526E-03	0.1418E-03
199	0.0995000	0.0248750	0.8530E-02	-0.8970E-04	0.2533E-03	0.8617E-04
200	0.0995000	0.0248750	0.8491E-02	-0.8514E-04	0.2538E-03	0.2886E-04
201	0.0995000	0.0248750	0.8673E-02	-0.1159E-03	0.2449E-03	0.2999E-03
202	0.0995000	0.0248750	0.8393E-02	-0.9755E-04	0.2455E-03	0.2348E-03
203	0.0995000	0.0248750	0.8272E-02	-0.9376E-04	0.2470E-03	0.1667E-03
204	0.0995000	0.0248750	0.8207E-02	-0.7426E-04	0.2485E-03	0.9914E-04
205	0.0995000	0.0248750	0.8179E-02	-0.6973E-04	0.2494E-03	0.3287E-04
206	0.0995000	0.0248750	0.8042E-02	-0.9791E-04	0.2337E-03	0.3536E-03
207	0.0995000	0.0248750	0.7922E-02	-0.7844E-04	0.2372E-03	0.2636E-03
208	0.0995000	0.0248750	0.7868E-02	-0.6517E-04	0.2407E-03	0.1814E-03
209	0.0995000	0.0248750	0.7806E-02	-0.5685E-04	0.2433E-03	0.1059E-03
210	0.0995000	0.0248750	0.7640E-02	-0.5293E-04	0.2446E-03	0.3481E-04
211	0.0995000	0.0248750	0.7349E-02	-0.7144E-04	0.2206E-03	0.3712E-03
212	0.0995000	0.0248750	0.7385E-02	-0.5592E-04	0.2280E-03	0.2668E-03
213	0.0995000	0.0248750	0.7435E-02	-0.4533E-04	0.2339E-03	0.1791E-03
214	0.0995000	0.0248750	0.7476E-02	-0.3896E-04	0.2379E-03	0.1030E-03
215	0.0995000	0.0248750	0.7500E-02	-0.3575E-04	0.2399E-03	0.3360E-04
216	0.0995000	0.0248750	0.6613E-02	-0.4313E-04	0.2070E-03	0.3354E-03
217	0.0995000	0.0248750	0.6847E-02	-0.3313E-04	0.2189E-03	0.2350E-03
218	0.0995000	0.0248750	0.7022E-02	-0.2625E-04	0.2275E-03	0.1548E-03
219	0.0995000	0.0248750	0.7138E-02	-0.2221E-04	0.2331E-03	0.8744E-04
220	0.0995000	0.0248750	0.7195E-02	-0.2026E-04	0.2358E-03	0.2850E-04
221	0.0995000	0.0248750	0.5956E-02	-0.1845E-04	0.1946E-03	0.2390E-03
222	0.0995000	0.0248750	0.6391E-02	-0.1411E-04	0.2110E-03	0.1645E-03
223	0.0995000	0.0248750	0.6690E-02	-0.1100E-04	0.2224E-03	0.1068E-03
224	0.0995000	0.0248750	0.6877E-02	-0.9152E-05	0.2295E-03	0.6014E-04
225	0.0995000	0.0248750	0.6968E-02	-0.8319E-05	0.2329E-03	0.1936E-04
226	0.0995000	0.0248750	0.5514E-02	-0.3901E-05	0.1854E-03	0.8769E-04
227	0.0995000	0.0248750	0.6106E-02	-0.3012E-05	0.2058E-03	0.5968E-04
228	0.0995000	0.0248750	0.6500E-02	-0.2491E-05	0.2193E-03	0.3855E-04
229	0.0995000	0.0248750	0.6740E-02	-0.1814E-05	0.2278E-03	0.2151E-04
230	**0.0995000**	**0.0248750**	**0.6855E-02**	-0.1797E-05	0.2317E-03	0.6978E-05
231	0.0497500	0.0248750	0.1031E-01	-0.2920E-04	0.3379E-03	-0.8940E-04
232	0.0497500	0.0248750	0.1016E-01	-0.8974E-04	0.3085E-03	0.5486E-06
233	0.0497500	0.0248750	0.9978E-02	-0.1215E-03	0.2897E-03	0.6908E-04
234	0.0497500	0.0248750	0.9709E-02	-0.1362E-03	0.2774E-03	0.1176E-03
235	0.0497500	0.0248750	0.9612E-02	-0.1409E-03	0.2695E-03	0.1477E-03
236	0.0497500	0.0248750	0.9450E-02	-0.1110E-03	0.2644E-03	0.1634E-03
237	0.0497500	0.0248750	0.1057E-01	-0.3529E-04	0.3276E-03	0.2914E-04
238	0.0497500	0.0248750	0.1032E-01	-0.1390E-03	0.2980E-03	0.1319E-03

Figure 4.11 Stress Distribution Values of Half Specimen Model Based on 1-Point Integration, where u' = 0.001", at Right Boundary Region

```
ELEMENT NO.   L            W            SIGY          SIGZ          SIGX          SIGYZ

    179   0.0995000    0.0570000    0.3823E-01   -0.5183E-03    0.1089E-02    0.1101E-04
    180   0.0995000    0.0570000    0.3829E-01   -0.5165E-03    0.1091E-02    0.1648E-05
    181   0.0995000    0.0570000    0.3642E-01   -0.4590E-03    0.1051E-02    0.1538E-03
    182   0.0995000    0.0570000    0.3751E-01   -0.5059E-03    0.1069E-02    0.8603E-04
    183   0.0995000    0.0570000    0.3800E-01   -0.5250E-03    0.1078E-02    0.3324E-04
    184   0.0995000    0.0570000    0.3821E-01   -0.5312E-03    0.1083E-02    0.1088E-04
    185   0.0995000    0.0570000    0.3828E-01   -0.5327E-03    0.1085E-02    0.2392E-05
    186   0.0995000    0.0570000    0.3628E-01   -0.4473E-03    0.1051E-02    0.6328E-04
    187   0.0995000    0.0570000    0.3742E-01   -0.5008E-03    0.1068E-02    0.3057E-04
    188   0.0995000    0.0570000    0.3797E-01   -0.5253E-03    0.1077E-02    0.1234E-04
    189   0.0995000    0.0570000    0.3819E-01   -0.5348E-03   -0.1081E-02    0.4308E-05
    190   0.0995000    0.0570000    0.3828E-01   -0.5378E-03    0.1082E-02    0.1012E-05
    191   0.0995000    0.0248750    0.3700E-01   -0.5228E-03    0.1045E-02    0.6454E-03
    192   0.0995000    0.0248750    0.3615E-01   -0.4781E-03    0.1034E-02    0.5792E-03
    193   0.0995000    0.0248750    0.3556E-01   -0.4354E-03    0.1032E-02    0.4454E-03
    194   0.0995000    0.0248750    0.3520E-01   -0.4041E-03    0.1032E-02    0.2774E-03
    195   0.0995000    0.0248750    0.3503E-01   -0.3878E-03    0.1032E-02    0.9396E-04
    196   0.0995000    0.0248750    0.3600E-01   -0.5054E-03    0.1019E-02    0.9103E-03
    197   0.0995000    0.0248750    0.3506E-01   -0.4412E-03    0.1012E-02    0.7589E-03
    198   0.0995000    0.0248750    0.3447E-01   -0.3692E-03    0.1013E-02    0.5594E-03
    199   0.0995000    0.0248750    0.3412E-01   -0.3539E-03    0.1015E-02    0.3401E-03
    200   0.0995000    0.0248750    0.3396E-01   -0.3361E-03    0.1017E-02    0.1139E-03
    201   0.0995000    0.0248750    0.3441E-01   -0.4604E-03    0.9832E-03    0.1185E-02
    202   0.0995000    0.0248750    0.3357E-01   -0.3847E-03    0.9845E-03    0.9281E-03
    203   0.0995000    0.0248750    0.3308E-01   -0.3291E-03    0.9901E-03    0.6591E-03
    204   0.0995000    0.0248750    0.3282E-01   -0.2931E-03    0.9955E-03    0.3922E-03
    205   0.0995000    0.0248750    0.3271E-01   -0.2754E-03    0.9987E-03    0.1300E-03
    206   0.0995000    0.0248750    0.3216E-01   -0.3637E-03    0.9378E-03    0.1400E-02
    207   0.0995000    0.0248750    0.3168E-01   -0.3090E-03    0.9508E-03    0.1043E-02
    208   0.0995000    0.0248750    0.3145E-01   -0.2570E-03    0.9639E-03    0.7152E-03
    209   0.0995000    0.0248750    0.3137E-01   -0.2245E-03    0.9738E-03    0.4195E-03
    210   0.0995000    0.0248750    0.3135E-01   -0.2087E-03    0.9791E-03    0.1379E-03
    211   0.0995000    0.0248750    0.2936E-01   -0.2813E-03    0.8846E-03    0.1470E-02
    212   0.0995000    0.0248750    0.2953E-01   -0.2201E-03    0.9134E-03    0.1057E-02
    213   0.0995000    0.0248750    0.2972E-01   -0.1787E-03    0.9363E-03    0.7096E-03
    214   0.0995000    0.0248750    0.2999E-01   -0.1534E-03    0.9519E-03    0.4081E-03
    215   0.0995000    0.0248750    0.3008E-01   -0.1413E-03    0.9598E-03    0.1331E-03
    216   0.0995000    0.0248750    0.2644E-01   -0.1695E-03    0.8293E-03    0.1327E-02
    217   0.0995000    0.0248750    0.2737E-01   -0.1392E-03    0.8761E-03    0.9303E-03
    218   0.0995000    0.0248750    0.2807E-01   -0.1035E-03    0.9102E-03    0.6129E-03
    219   0.0995000    0.0248750    0.2853E-01   -0.8766E-04    0.9321E-03    0.3484E-03
    220   0.0995000    0.0248750    0.2876E-01   -0.8009E-04    0.9428E-03    0.1129E-03
    221   0.0995000    0.0248750    0.23-3E-01   -0.7225E-04    0.7793E-03    0.9444E-03
    222   0.0995000    0.0248750    0.2555E-01   -0.5530E-04    0.8443E-03    0.6505E-03
    223   0.0995000    0.0248750    0.2674E-01   -0.4323E-04    0.8892E-03    0.4228E-03
    224   0.0995000    0.0248750    0.2748E-01   -0.3610E-04    0.9172E-03    0.2383E-03
    225   0.0995000    0.0248750    0.2784E-01   -0.3288E-04    0.9307E-03    0.7676E-04
    226   0.0995000    0.0248750    0.2208E-01   -0.1518E-04    0.7424E-03    0.3455E-03
    227   0.0995000    0.0248750    0.2442E-01   -0.1172E-04    0.8232E-03    0.2359E-03
    228   0.0995000    0.0248750    0.2598E-01   -0.9719E-05    0.8766E-03    0.1529E-03
    229   0.0995000    0.0248750    0.2693E-01   -0.7108E-05    0.9101E-03    0.8553E-04
    230   0.0995000    0.0248750    0.2738E-01   -0.7017E-05    0.9255E-03    0.2778E-04
    231   0.0497500    0.0248750    0.1119E-01   -0.1074E-03    0.1353E-02   -0.3712E-03
    232   0.0497500    0.0248750    0.4060E-01   -0.3491E-03    0.1237E-02   -0.1555E-04
    233   0.0497500    0.0248750    0.3988E-01   -0.4745E-03    0.1162E-02    0.2588E-03
    234   0.0497500    0.0248750    0.3914E-01   -0.5333E-03    0.1114E-02    0.4512E-03
    235   0.0497500    0.0248750    0.3844E-01   -0.5526E-03    0.1082E-02    0.5726E-03
    236   0.0497500    0.0248750    0.3779E-01   -0.5495E-03    0.1052E-02    0.6372E-03
    237   0.0497500    0.0248750    0.4261E-01   -0.3294E-03    0.1314E-02    0.8836E-04
    238   0.0497500    0.0248750    0.4128E-01   -0.5089E-03    0.1196E-02    0.4999E-03
```

Figure 4.12 Stress Distribution Values of Half Specimen Model Based on 1-Point Integration, where u' = 0.004", at Right Boundary Region

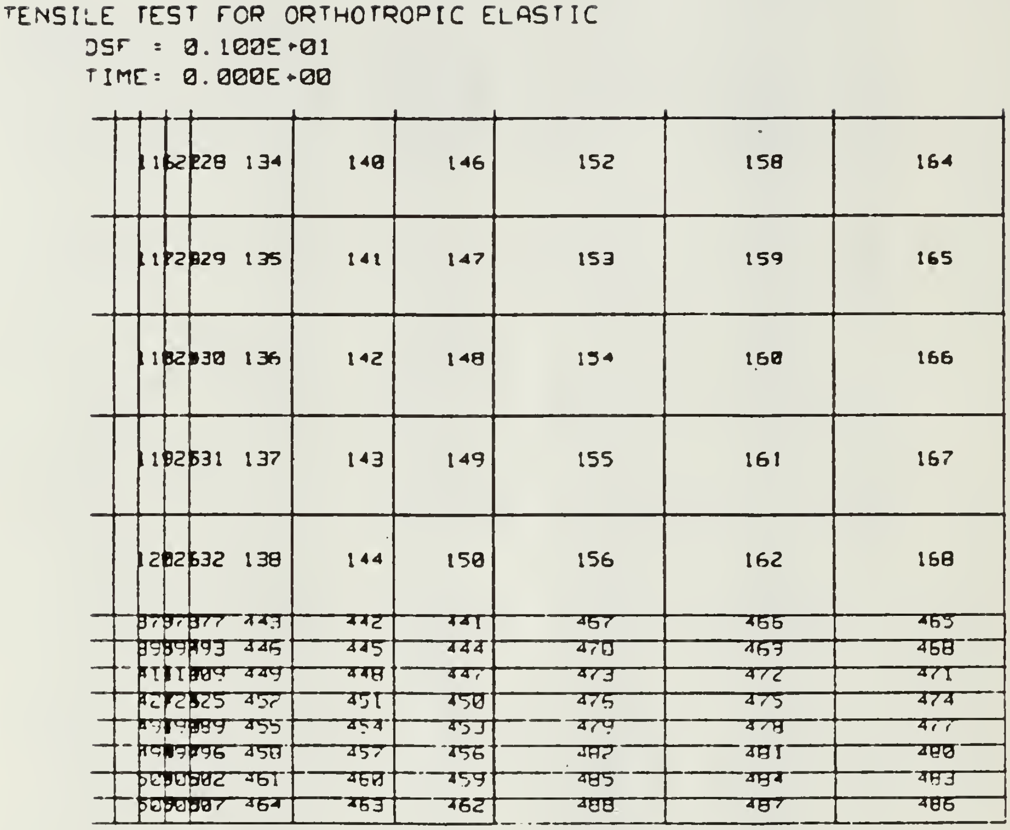


Figure 4.13 Element Numbers of Entire Specimen Model at Bottom-Right Boundary Region

TABLE 4.1

AVERAGE STRESS FOR HALF SPECIMEN MODEL WITH NOTCH

ELEMENT		σ_y , Msi.		
NUMBER	WIDTH, IN.	U' = 0.001"	U' = 0.004"	U' = 0.01"
186	0.057000	0.009071	0.036280	0.090670
187	0.057000	0.009358	0.037420	0.090350
188	0.057000	0.009496	0.037970	0.094830
189	0.057000	0.009554	0.038190	0.095370
190	0.057000	0.009750	0.038280	0.095570
195	0.024875	0.008758	0.035030	0.087550
200	0.024875	0.008491	0.033960	0.084860
205	0.024875	0.008179	0.032710	0.081700
210	0.024875	0.007840	0.031350	0.078260
215	0.024875	0.007500	0.029980	0.074810
220	0.024875	0.007195	0.028760	0.071720
225	0.024875	0.006968	0.027840	0.069400
230	0.024875	0.006855	0.027880	0.068220
	PBAR*	0.008717	0.034850	0.087045

* Average boundary stress

TABLE 4. 2

AVERAGE STRESS FOR FULL SPECIMEN MODEL WITH NOTCH

ELEMENT		σ_y , Msi.
NUMBER	WIDTH, IN.	U' = 0.01"
163, 166	0.095000	0.091560
164, 167	0.095000	0.094940
165, 168	0.095000	0.095670
171, 465	0.024875	0.087600
174, 468	0.024875	0.084860
177, 471	0.024875	0.081660
180, 474	0.024875	0.078170
183, 477	0.024875	0.074670
186, 480	0.024875	0.071540
189, 483	0.024875	0.069200
192, 486	0.024875	0.068030
	PBAR*	0.078025

* Average boundary stress

TABLE 4.3-A

STATISTICAL DATA SUMMARY

FOR PLATE WITH NOTCH, $\alpha = 10$, $\beta = 0.1$, $k_C = 0.001$

MODEL	HALF			FULL
DISPLACEMENT LIST	U'=0.001"	U'=0.004"	U'=0.01"	U'=0.01"
PBAR*	0.008717	0.034850	0.087045	0.087025
β_E	0.030582	0.030749	0.031110	0.028880

TABLE 4.3-B

STATISTICAL DATA SUMMARY

FOR PLATE WITH NOTCH, $\alpha = 20$, $\beta = 0.1$, $k_C = 0.0001$

MODEL	HALF			FULL
DISPLACEMENT LIST	U'=0.001"	U'=0.004"	U'=0.01"	U'=0.01"
PBAR*	0.008717	0.034850	0.087045	0.087025
β_E	0.029122	0.029298	0.029721	0.028826

* Average boundary stress

TABLE 4.3-C

STATISTICAL DATA SUMMARY

FOR PLATE WITHOUT NOTCH, $\alpha = 10$, $\beta = 0.1$, $k_C = 0.001$

DISPLACEMENT / LIST	U'=0.001"	U'=0.01"
PBAR*	0.009512	0.094910
β_E	0.043948	0.043948

TABLE 4.3-D

STATISTICAL DATA SUMMARY

FOR PLATE WITHOUT NOTCH, $\alpha = 20$, $\beta = 0.1$, $k_C = 0.0001$

DISPLACEMENT / LIST	U'=0.001"	U'=0.01"
PBAR*	0.009512	0.09491
β_E	0.051800	0.05180

* Average boundary stress

APPENDIX A

STATISTICAL STRUCTURAL RELIABILITY PROGRAM

```
C*********************************************************************
CC
C*********************************************************************
C
C*********************************************************************
C
C PROGRAM: RELIABILITY CALCULATION OF PLATE MODEL BASED ON
C
C        -  LINEARIZE SIZE EFFECT, NONUNIFORM UNIAXIAL STRESS.
C
C           RELIABILITY FORMULATION IS EXPRESSED IN THE
C
C           " STANDARD WEIBULL FORM ".
C
C DATA INPUT: OUTPUT OF FINITE ELEMENT CODE NAME " NIKE2D"
C
C*********************************************************************
C
C
C VARIABLE: KC = MATERIAL CONSTANT FOR PLATE THAT IS
C
C                SUBJECTED TO UNIFORM TENSILE STRESS. IN
C
C                THIS CASE, ASSUME IN EACH ELEMENT THE
C
C                LOCAL TENSILE STRESS IS UNIFORM.
C
C           BETA = SCALE PARAMETER FROM EXPERIMENTAL RESULT
C
C                FROM SEVERAL NUMBERS OF SAMPLE.
C
C           ALPHA = SHAPE PARAMETER FROM EXPERIMENTAL RESULT
C
C                FROM SEVERAL NUMBERS OF SAMPLE.
C
C           PBAR = AVERAGE STRESS ALONG BOUDARY SIDE OF THE
C
C                PLATE THAT SUBJECTED TO THE EXTERNAL FORCES.
C
C                IT MUST BE CALCULATED SEPARATELY AFTER OBTAINING
C
C                THE STRESS RESULTS FROM "NIKE2D" PROGRAM.
C
C           NE = NUMBER OF ELEMENTS OBTAINING FROM MESH GENERATOR
C
C                PROGRAM NAME "MAZE" WHICH IS THE PROGRAM THAT
C
C                CREATE AN INPUT FILE TO BE USED IN "NIKE2D"
C
C                PROGRAM. ALSO BOUNDARY ELEMENT NUMBERS CAN BE
C
C                CREATED FROM "MAZE" PROGRAM.
C
C
C
C
      DOUBLE PRECISION F,FA,FF,P(1000),RA(1000),BETAA
      DIMENSION XL(2368),XW(2368),SIGY(2368)
      REAL KC
      BYTE A(30)
      TYPE*,'ENTER FILE CONTAINING STRESSES DATA INPUT'
      READ(5,5) A
    5 FORMAT(30A1)
      OPEN(UNIT=4, FILE=A, STATUS='OLD')
      OPEN(UNIT=6, FILE='SS.DAT', STATUS='NEW')
      WRITE(6,1)
    1 FORMAT(3X,'DATA OUTPUT FOR LINEARIZE SIZE EFFECT
     *UNIAXIAL TENSILE STRESS')
      TYPE*,'ENTER  1  FOR PLATE WITH NOTCH
     *         OTHERWISE FOR PLATE WITHOUT NOTCH'
      READ*,NC
      IF(NC.EQ.1) THEN
         WRITE(6,2)
      ELSE
         WRITE(6,22)
      END IF
    2 FORMAT(20X,'FOR PLATE WITH NOTCH')
   22 FORMAT(18X,'FOR PLATE WITHOUT NOTCH')
      TYPE*,'ENTER THE VALUE OF DISPLACEMENT BOUNDARY CONDITION'
      READ*,U
      WRITE(6,3) U
      TYPE*,'ENTER  1  FOR ENTIRE SPECIMEN INPUT
     *         OTHERWISE FOR HALF SPECIMEN INPUT'
      READ*,NS
      IF(NS.EQ.1) THEN
         WRITE(6,23)
      ELSE
         WRITE(6,24)
      END IF
   23 FORMAT(15X,'ENTIRE SPECIMEN MODEL INPUT')
   24 FORMAT(16X,'HALF SPECIMEN MODEL INPUT')
    3 FORMAT(7X,'WHERE THE DISPLACEMENT BOUNDARY CONDITION IS ',F8.4)
      TYPE*,'ENTER THE KC VALUE'
      READ*,KC
      TYPE*,'ENTER THE BETA VALUE'
      READ*,BETA
      TYPE*,'ENTER THE ALPHA VALUE'
      READ*,ALPHA
      ALPHA2=ALPHA+2.0
      FF=0.0
      TYPE*,'ENTER THE PBAR VALUE'
      READ*,PBAR
      TYPE*,'ENTER THE NUMBER OF ELEMENTS'
      READ*,NE
C
C     READ ELEMENT LENGTH, WIDTH, AND TENSILE STRESS FROM INPUT FILE
C
C     CALCULATE BETAA WHICH IS BETA THAT CHANGED WITH GEOMETRY OF THE
C
C     SPECIMEN MODEL AND CERTAIN LOADING BOUNDARY CONDITION BUT IT IS
C
C     INDEPENDENT OF THE VALUE OF LOAD UNDER THE SAME BOUNDARY CONDITION.
C
      DO 200 I=1,NE
         READ(4,20) XL(I),XW(I),SIGY(I)
         IF(SIGY(I).GT.0.0) THEN
          F=(XL(I)*XW(I)/KC**2.0)
     *      *(SIGY(I)**ALPHA2)
         FF=FF+F
         ELSE
```

```
            FF=FF
          END IF
 200  CONTINUE
      IF(NS.EQ.1) THEN
         FF=FF
      ELSE
         FF=FF*2.0
      END IF
      FA=FF**(-1./ALPHA2)*PBAR
      BETAA=BETA**(ALPHA/ALPHA2)*FA
      WRITE(6,10) KC
  10  FORMAT(8X,'KC =',F13.8)
      WRITE(6,11) BETA
  11  FORMAT(6X,'BETA =',F13.8)
      WRITE(6,12) ALPHA
  12  FORMAT(5X,'ALPHA =',F13.8)
      WRITE(6,13) PBAR
  13  FORMAT(6X,'PBAR =',F13.8)
      WRITE(6,14) NE
  14  FORMAT(8X,'NE =',I4)
      WRITE(6,15) ALPHA2
  15  FORMAT(4X,'ALPHA2 =',F13.8)
      WRITE(6,25) BETAA
      TYPE*,'ENTER THE FIRST EXTERNAL LOAD'
      READ*,P(1)
      PINC=P(1)/30.
C
C     RELIABILITY CALCULATION BASED ON LINEARIZE SIZE EFFECT.
C
      DO 100 J=1,100
         RA(J)=DEXP(-(P(J)/BETAA)**ALPHA2)
         WRITE(6,30) J,P(J),RA(J)
         P(J+1)=P(J)+PINC
 100  CONTINUE
  20  FORMAT(8X,2F11.0,E12.0)
  25  FORMAT(5X,'BETAA =',F13.8)
  30  FORMAT(9X,'J =',I4,3X,'P =',F13.8,3X,'RA =',F13.8)
      STOP
      END
```

APPENDIX B

DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                      FOR PLATE WITH NOTCH
     WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0010
                    HALF SPECIMEN MODEL INPUT
      KC =    0.00010000
    BETA =    0.10000000
   ALPHA =   20.00000000
    PBAR =    0.00871700
      NE = 482
  ALPHA2 =   22.00000000
   BETAA =    0.02912212
       J =    1     P =     0.00871700    RA =     1.00000000
       J =    2     P =     0.00900757    RA =     1.00000000
       J =    3     P =     0.00929813    RA =     1.00000000
       J =    4     P =     0.00958870    RA =     1.00000000
       J =    5     P =     0.00987927    RA =     1.00000000
       J =    6     P =     0.01016983    RA =     1.00000000
       J =    7     P =     0.01046040    RA =     1.00000000
       J =    8     P =     0.01075097    RA =     1.00000000
       J =    9     P =     0.01104153    RA =     1.00000000
       J =   10     P =     0.01133210    RA =     1.00000000
       J =   11     P =     0.01162267    RA =     1.00000000
       J =   12     P =     0.01191323    RA =     1.00000000
       J =   13     P =     0.01220380    RA =     1.00000000
       J =   14     P =     0.01249437    RA =     0.99999999
       J =   15     P =     0.01278493    RA =     0.99999999
       J =   16     P =     0.01307550    RA =     0.99999998
       J =   17     P =     0.01336607    RA =     0.99999996
       J =   18     P =     0.01365663    RA =     0.99999994
       J =   19     P =     0.01394720    RA =     0.99999991
       J =   20     P =     0.01423777    RA =     0.99999985
       J =   21     P =     0.01452833    RA =     0.99999977
       J =   22     P =     0.01481890    RA =     0.99999965
       J =   23     P =     0.01510947    RA =     0.99999946
       J =   24     P =     0.01540003    RA =     0.99999918
       J =   25     P =     0.01569060    RA =     0.99999877
       J =   26     P =     0.01598117    RA =     0.99999815
       J =   27     P =     0.01627173    RA =     0.99999725
       J =   28     P =     0.01656230    RA =     0.99999595
       J =   29     P =     0.01685287    RA =     0.99999406
       J =   30     P =     0.01714343    RA =     0.99999135
       J =   31     P =     0.01743400    RA =     0.99998747
       J =   32     P =     0.01772457    RA =     0.99998198
       J =   33     P =     0.01801513    RA =     0.99997423
       J =   34     P =     0.01830570    RA =     0.99996336
       J =   35     P =     0.01859627    RA =     0.99994819
       J =   36     P =     0.01888683    RA =     0.99992712
       J =   37     P =     0.01917740    RA =     0.99989804
       J =   38     P =     0.01946797    RA =     0.99985806
       J =   39     P =     0.01975853    RA =     0.99980337
       J =   40     P =     0.02004910    RA =     0.99972890
       J =   41     P =     0.02033967    RA =     0.99962797
       J =   42     P =     0.02063023    RA =     0.99949175
       J =   43     P =     0.02092080    RA =     0.99930870
       J =   44     P =     0.02121137    RA =     0.99906373
       J =   45     P =     0.02150193    RA =     0.99873722
       J =   46     P =     0.02179250    RA =     0.99830378
       J =   47     P =     0.02208307    RA =     0.99773061
       J =   48     P =     0.02237363    RA =     0.99697558
       J =   49     P =     0.02266420    RA =     0.99598476
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITH NOTCH
    WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
                  HALF SPECIMEN MODEL INPUT
       KC =   0.00010000
     BETA =   0.10000000
    ALPHA =  20.00000000
     PBAR =   0.08704500
       NE = 482
   ALPHA2 =  22.00000000
    BETAA =   0.02972093
          J =    1    P =    0.00871700    RA =    1.00000000
          J =    2    P =    0.00900757    RA =    1.00000000
          J =    3    P =    0.00929813    RA =    1.00000000
          J =    4    P =    0.00958870    RA =    1.00000000
          J =    5    P =    0.00987927    RA =    1.00000000
          J =    6    P =    0.01016983    RA =    1.00000000
          J =    7    P =    0.01046040    RA =    1.00000000
          J =    8    P =    0.01075097    RA =    1.00000000
          J =    9    P =    0.01104153    RA =    1.00000000
          J =   10    P =    0.01133210    RA =    1.00000000
          J =   11    P =    0.01162267    RA =    1.00000000
          J =   12    P =    0.01191323    RA =    1.00000000
          J =   13    P =    0.01220380    RA =    1.00000000
          J =   14    P =    0.01249437    RA =    0.99999999
          J =   15    P =    0.01278493    RA =    0.99999999
          J =   16    P =    0.01307550    RA =    0.99999999
          J =   17    P =    0.01336607    RA =    0.99999998
          J =   18    P =    0.01365663    RA =    0.99999996
          J =   19    P =    0.01394720    RA =    0.99999994
          J =   20    P =    0.01423777    RA =    0.99999991
          J =   21    P =    0.01452833    RA =    0.99999985
          J =   22    P =    0.01481890    RA =    0.99999978
          J =   23    P =    0.01510947    RA =    0.99999966
          J =   24    P =    0.01540003    RA =    0.99999948
          J =   25    P =    0.01569060    RA =    0.99999921
          J =   26    P =    0.01598117    RA =    0.99999882
          J =   27    P =    0.01627173    RA =    0.99999825
          J =   28    P =    0.01656230    RA =    0.99999741
          J =   29    P =    0.01685287    RA =    0.99999620
          J =   30    P =    0.01714343    RA =    0.99999447
          J =   31    P =    0.01743400    RA =    0.99999200
          J =   32    P =    0.01772457    RA =    0.99998848
          J =   33    P =    0.01801513    RA =    0.99998353
          J =   34    P =    0.01830570    RA =    0.99997658
          J =   35    P =    0.01859627    RA =    0.99996689
          J =   36    P =    0.01888683    RA =    0.99995343
          J =   37    P =    0.01917740    RA =    0.99993484
          J =   38    P =    0.01946797    RA =    0.99990929
          J =   39    P =    0.01975853    RA =    0.99987434
          J =   40    P =    0.02004910    RA =    0.99982675
          J =   41    P =    0.02033967    RA =    0.99976224
          J =   42    P =    0.02063023    RA =    0.99967518
          J =   43    P =    0.02092080    RA =    0.99955817
          J =   44    P =    0.02121137    RA =    0.99940158
          J =   45    P =    0.02150193    RA =    0.99919284
          J =   46    P =    0.02179250    RA =    0.99891570
          J =   47    P =    0.02208307    RA =    0.99854916
          J =   48    P =    0.02237363    RA =    0.99806620
          J =   49    P =    0.02266420    RA =    0.99743222
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITH NOTCH
     WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0040
                 HALF SPECIMEN MODEL INPUT
        KC  =   0.00010000
      BETA  =   0.10000000
     ALPHA  =  20.00000000
      PBAR  =   0.03485000
        NE  = 482
    ALPHA2  =  22.00000000
     BETAA  =   0.02929771
           J  =   1    P  =    0.00871700    RA  =    1.00000000
           J  =   2    P  =    0.00900757    RA  =    1.00000000
           J  =   3    P  =    0.00929813    RA  =    1.00000000
           J  =   4    P  =    0.00958870    RA  =    1.00000000
           J  =   5    P  =    0.00987927    RA  =    1.00000000
           J  =   6    P  =    0.01016983    RA  =    1.00000000
           J  =   7    P  =    0.01046040    RA  =    1.00000000
           J  =   8    P  =    0.01075097    RA  =    1.00000000
           J  =   9    P  =    0.01104153    RA  =    1.00000000
           J  =  10    P  =    0.01133210    RA  =    1.00000000
           J  =  11    P  =    0.01162267    RA  =    1.00000000
           J  =  12    P  =    0.01191323    RA  =    1.00000000
           J  =  13    P  =    0.01220380    RA  =    1.00000000
           J  =  14    P  =    0.01249437    RA  =    0.99999999
           J  =  15    P  =    0.01278493    RA  =    0.99999999
           J  =  16    P  =    0.01307550    RA  =    0.99999998
           J  =  17    P  =    0.01336607    RA  =    0.99999997
           J  =  18    P  =    0.01365663    RA  =    0.99999995
           J  =  19    P  =    0.01394720    RA  =    0.99999992
           J  =  20    P  =    0.01423777    RA  =    0.99999987
           J  =  21    P  =    0.01452833    RA  =    0.99999980
           J  =  22    P  =    0.01481890    RA  =    0.99999969
           J  =  23    P  =    0.01510947    RA  =    0.99999953
           J  =  24    P  =    0.01540003    RA  =    0.99999928
           J  =  25    P  =    0.01569060    RA  =    0.99999892
           J  =  26    P  =    0.01598117    RA  =    0.99999838
           J  =  27    P  =    0.01627173    RA  =    0.99999759
           J  =  28    P  =    0.01656230    RA  =    0.99999645
           J  =  29    P  =    0.01685297    RA  =    0.99999479
           J  =  30    P  =    0.01714343    RA  =    0.99999242
           J  =  31    P  =    0.01743400    RA  =    0.99998903
           J  =  32    P  =    0.01772457    RA  =    0.99998421
           J  =  33    P  =    0.01801513    RA  =    0.99997742
           J  =  34    P  =    0.01830570    RA  =    0.99996790
           J  =  35    P  =    0.01859627    RA  =    0.99995460
           J  =  36    P  =    0.01888683    RA  =    0.99993615
           J  =  37    P  =    0.01917740    RA  =    0.99991067
           J  =  38    P  =    0.01946797    RA  =    0.99987564
           J  =  39    P  =    0.01975853    RA  =    0.99982772
           J  =  40    P  =    0.02004910    RA  =    0.99976248
           J  =  41    P  =    0.02033967    RA  =    0.99967405
           J  =  42    P  =    0.02063023    RA  =    0.99955470
           J  =  43    P  =    0.02092040    RA  =    0.99939431
           J  =  44    P  =    0.02121137    RA  =    0.99917967
           J  =  45    P  =    0.02150193    RA  =    0.99889357
           J  =  46    P  =    0.02179250    RA  =    0.99851375
           J  =  47    P  =    0.02208307    RA  =    0.99801137
           J  =  48    P  =    0.02237363    RA  =    0.99734976
           J  =  49    P  =    0.02266420    RA  =    0.99648130
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILF STRESS
                    FOR PLATE WITHOHT NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS     0.0010
                 ENTIRE SPECIMEN MODEL INPUT
     KC =    0.00010000
   BETA =    0.10000000
  ALPHA =   20.00000000
   PBAR =    0.00951200
     NE =  200
 ALPHAZ =   22.00000000
  BETAA =    0.05180000
        J =    1    P =    0.00871700    RA =    1.00000000
        J =    2    P =    0.00900757    RA =    1.00000000
        J =    3    P =    0.00929813    RA =    1.00000000
        J =    4    P =    0.00958870    RA =    1.00000000
        J =    5    P =    0.00987927    RA =    1.00000000
        J =    6    P =    0.01016983    RA =    1.00000000
        J =    7    P =    0.01046040    RA =    1.00000000
        J =    8    P =    0.01075097    RA =    1.00000000
        J =    9    P =    0.01104153    RA =    1.00000000
        J =   10    P =    0.01133210    RA =    1.00000000
        J =   11    P =    0.01162267    RA =    1.00000000
        J =   12    P =    0.01191323    RA =    1.00000000
        J =   13    P =    0.01220380    RA =    1.00000000
        J =   14    P =    0.01249437    RA =    1.00000000
        J =   15    P =    0.01278493    RA =    1.00000000
        J =   16    P =    0.01307550    RA =    1.00000000
        J =   17    P =    0.01336607    RA =    1.00000000
        J =   18    P =    0.01365663    RA =    1.00000000
        J =   19    P =    0.01394720    RA =    1.00000000
        J =   20    P =    0.01423777    RA =    1.00000000
        J =   21    P =    0.01452833    RA =    1.00000000
        J =   22    P =    0.01481890    RA =    1.00000000
        J =   23    P =    0.01510947    RA =    1.00000000
        J =   24    P =    0.01540003    RA =    1.00000000
        J =   25    P =    0.01569060    RA =    1.00000000
        J =   26    P =    0.01598117    RA =    1.00000000
        J =   27    P =    0.01627173    RA =    1.00000000
        J =   28    P =    0.01656230    RA =    1.00000000
        J =   29    P =    0.01685287    RA =    1.00000000
        J =   30    P =    0.01714343    RA =    1.00000000
        J =   31    P =    0.01743400    RA =    1.00000000
        J =   32    P =    0.01772457    RA =    1.00000000
        J =   33    P =    0.01801513    RA =    1.00000000
        J =   34    P =    0.01830570    RA =    1.00000000
        J =   35    P =    0.01859627    RA =    1.00000000
        J =   36    P =    0.01888683    RA =    1.00000000
        J =   37    P =    0.01917740    RA =    1.00000000
        J =   38    P =    0.01946797    RA =    1.00000000
        J =   39    P =    0.01975853    RA =    1.00000000
        J =   40    P =    0.02004910    RA =    1.00000000
        J =   41    P =    0.02033967    RA =    1.00000000
        J =   42    P =    0.02063023    RA =    1.00000000
        J =   43    P =    0.02092080    RA =    1.00000000
        J =   44    P =    0.02121137    RA =    1.00000000
        J =   45    P =    0.02150193    RA =    1.00000000
        J =   46    P =    0.02179250    RA =    0.99999999
        J =   47    P =    0.02208307    RA =    0.99999999
        J =   48    P =    0.02237363    RA =    0.99999999
        J =   49    P =    0.02266420    RA =    0.99999999
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                  FOR PLATE WITHOUT NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
              ENTIRE SPECIMEN MODEL INPUT
     KC  =    0.00010000
   BETA  =    0.10000000
  ALPHA  =   20.00000000
   PBAR  =    0.09491000
     NE  = 200
 ALPHA2  =   22.00000000
  BETAA  =    0.05180009
        J  =    1    P  =    0.00871700    RA  =    1.00000000
        J  =    2    P  =    0.00900757    RA  =    1.00000000
        J  =    3    P  =    0.00929813    RA  =    1.00000000
        J  =    4    P  =    0.00958870    RA  =    1.00000000
        J  =    5    P  =    0.00987927    RA  =    1.00000000
        J  =    6    P  =    0.01016983    RA  =    1.00000000
        J  =    7    P  =    0.01046040    RA  =    1.00000000
        J  =    8    P  =    0.01075097    RA  =    1.00000000
        J  =    9    P  =    0.01104153    RA  =    1.00000000
        J  =   10    P  =    0.01133210    RA  =    1.00000000
        J  =   11    P  =    0.01162267    RA  =    1.00000000
        J  =   12    P  =    0.01191323    RA  =    1.00000000
        J  =   13    P  =    0.01220380    RA  =    1.00000000
        J  =   14    P  =    0.01249437    RA  =    1.00000000
        J  =   15    P  =    0.01278493    RA  =    1.00000000
        J  =   16    P  =    0.01307550    RA  =    1.00000000
        J  =   17    P  =    0.01336607    RA  =    1.00000000
        J  =   18    P  =    0.01365663    RA  =    1.00000000
        J  =   19    P  =    0.01394720    RA  =    1.00000000
        J  =   20    P  =    0.01423777    RA  =    1.00000000
        J  =   21    P  =    0.01452833    RA  =    1.00000000
        J  =   22    P  =    0.01481890    RA  =    1.00000000
        J  =   23    P  =    0.01510947    RA  =    1.00000000
        J  =   24    P  =    0.01540003    RA  =    1.00000000
        J  =   25    P  =    0.01569060    RA  =    1.00000000
        J  =   26    P  =    0.01598117    RA  =    1.00000000
        J  =   27    P  =    0.01627173    RA  =    1.00000000
        J  =   28    P  =    0.01656231    RA  =    1.00000000
        J  =   29    P  =    0.01685287    RA  =    1.00000000
        J  =   30    P  =    0.01714343    RA  =    1.00000000
        J  =   31    P  =    0.01743400    RA  =    1.00000000
        J  =   32    P  =    0.01772457    RA  =    1.00000000
        J  =   33    P  =    0.01801513    RA  =    1.00000000
        J  =   34    P  =    0.01830570    RA  =    1.00000000
        J  =   35    P  =    0.01859627    RA  =    1.00000000
        J  =   36    P  =    0.01888683    RA  =    1.00000000
        J  =   37    P  =    0.01917740    RA  =    1.00000000
        J  =   38    P  =    0.01946797    RA  =    1.00000000
        J  =   39    P  =    0.01975853    RA  =    1.00000000
        J  =   40    P  =    0.02004910    RA  =    1.00000000
        J  =   41    P  =    0.02033967    RA  =    1.00000000
        J  =   42    P  =    0.02063023    RA  =    1.00000000
        J  =   43    P  =    0.02092080    RA  =    1.00000000
        J  =   44    P  =    0.02121137    RA  =    1.00000000
        J  =   45    P  =    0.02150193    RA  =    1.00000000
        J  =   46    P  =    0.02179250    RA  =    0.99999999
        J  =   47    P  =    0.02208307    RA  =    0.99999999
        J  =   48    P  =    0.02237363    RA  =    0.99999999
        J  =   49    P  =    0.02266420    RA  =    0.99999999
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITH NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
                ENTIRE SPECIMEN MODEL INPUT
     KC =    0.00010000
   BETA =    0.10000000
  ALPHA =   20.00000000
   PBAR =    0.08702500
     NE =  592
 ALPHA2 =   22.00000000
  BETAA =    0.00288262
       J =   1   P =    0.00871700   RA =    1.00000000
       J =   2   P =    0.00900757   RA =    1.00000000
       J =   3   P =    0.00929813   RA =    1.00000000
       J =   4   P =    0.00958870   RA =    1.00000000
       J =   5   P =    0.00987927   RA =    1.00000000
       J =   6   P =    0.01016983   RA =    1.00000000
       J =   7   P =    0.01046040   RA =    1.00000000
       J =   8   P =    0.01075097   RA =    1.00000000
       J =   9   P =    0.01104153   RA =    1.00000000
       J =  10   P =    0.01133210   RA =    1.00000000
       J =  11   P =    0.01162267   RA =    1.00000000
       J =  12   P =    0.01191323   RA =    1.00000000
       J =  13   P =    0.01220380   RA =    0.99999999
       J =  14   P =    0.01249437   RA =    0.99999999
       J =  15   P =    0.01278493   RA =    0.99999998
       J =  16   P =    0.01307550   RA =    0.99999997
       J =  17   P =    0.01336607   RA =    0.99999995
       J =  18   P =    0.01365663   RA =    0.99999992
       J =  19   P =    0.01394720   RA =    0.99999988
       J =  20   P =    0.01423777   RA =    0.99999981
       J =  21   P =    0.01452833   RA =    0.99999971
       J =  22   P =    0.01481890   RA =    0.99999954
       J =  23   P =    0.01510947   RA =    0.99999930
       J =  24   P =    0.01540003   RA =    0.99999894
       J =  25   P =    0.01569060   RA =    0.99999840
       J =  26   P =    0.01598117   RA =    0.99999760
       J =  27   P =    0.01627173   RA =    0.99999643
       J =  28   P =    0.01656230   RA =    0.99999474
       J =  29   P =    0.01685287   RA =    0.99999228
       J =  30   P =    0.01714343   RA =    0.99998876
       J =  31   P =    0.01743400   RA =    0.99998373
       J =  32   P =    0.01772457   RA =    0.99997660
       J =  33   P =    0.01801513   RA =    0.99996653
       J =  34   P =    0.01830570   RA =    0.99995241
       J =  35   P =    0.01859627   RA =    0.99993271
       J =  36   P =    0.01888683   RA =    0.99990536
       J =  37   P =    0.01917740   RA =    0.99986759
       J =  38   P =    0.01946797   RA =    0.99981567
       J =  39   P =    0.01975853   RA =    0.99974465
       J =  40   P =    0.02004910   RA =    0.99964795
       J =  41   P =    0.02033967   RA =    0.99951688
       J =  42   P =    0.02063023   RA =    0.99934001
       J =  43   P =    0.02092080   RA =    0.99910233
       J =  44   P =    0.02121137   RA =    0.99878427
       J =  45   P =    0.02150193   RA =    0.99836039
       J =  46   P =    0.02179250   RA =    0.99779774
       J =  47   P =    0.02208307   RA =    0.99705383
       J =  48   P =    0.02237363   RA =    0.99607408
       J =  49   P =    0.02266420   RA =    0.99478870
       J =  50   P =    0.02295477   RA =    0.99310881
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                   FOR PLATE WITH NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0010
                 HALF SPECIMEN MODEL INPUT
      KC =    0.00100000
    BETA =    0.10000000
   ALPHA =   10.00000000
    PBAR =    0.00871700
      NE =  482
  ALPHA2 =   12.00000000
   BETAA =    0.03058189
         J =   1    P =    0.00871700    RA =    0.99999971
         J =   2    P =    0.00900757    RA =    0.99999957
         J =   3    P =    0.00929813    RA =    0.99999938
         J =   4    P =    0.00958870    RA =    0.99999910
         J =   5    P =    0.00987927    RA =    0.99999871
         J =   6    P =    0.01016983    RA =    0.99999817
         J =   7    P =    0.01046040    RA =    0.99999744
         J =   8    P =    0.01075097    RA =    0.99999644
         J =   9    P =    0.01104153    RA =    0.99999509
         J =  10    P =    0.01133210    RA =    0.99999330
         J =  11    P =    0.01162267    RA =    0.99999092
         J =  12    P =    0.01191323    RA =    0.99998779
         J =  13    P =    0.01220380    RA =    0.99998369
         J =  14    P =    0.01249437    RA =    0.99997837
         J =  15    P =    0.01278493    RA =    0.99997150
         J =  16    P =    0.01307550    RA =    0.99996268
         J =  17    P =    0.01336607    RA =    0.99995142
         J =  18    P =    0.01365663    RA =    0.99993712
         J =  19    P =    0.01394720    RA =    0.99991904
         J =  20    P =    0.01423777    RA =    0.99989632
         J =  21    P =    0.01452833    RA =    0.99986787
         J =  22    P =    0.01481890    RA =    0.99983244
         J =  23    P =    0.01510947    RA =    0.99978847
         J =  24    P =    0.01540003    RA =    0.99973415
         J =  25    P =    0.01569060    RA =    0.99966732
         J =  26    P =    0.01598117    RA =    0.99958539
         J =  27    P =    0.01627173    RA =    0.99948534
         J =  28    P =    0.01656230    RA =    0.99936359
         J =  29    P =    0.01685287    RA =    0.99921595
         J =  30    P =    0.01714343    RA =    0.99903752
         J =  31    P =    0.01743400    RA =    0.99882257
         J =  32    P =    0.01772457    RA =    0.99856443
         J =  33    P =    0.01801513    RA =    0.99825539
         J =  34    P =    0.01830570    RA =    0.99788649
         J =  35    P =    0.01859627    RA =    0.99744740
         J =  36    P =    0.01888683    RA =    0.99692624
         J =  37    P =    0.01917740    RA =    0.99630936
         J =  38    P =    0.01946797    RA =    0.99558110
         J =  39    P =    0.01975853    RA =    0.99472362
         J =  40    P =    0.02004910    RA =    0.99371655
         J =  41    P =    0.02033967    RA =    0.99253675
         J =  42    P =    0.02063023    RA =    0.99115800
         J =  43    P =    0.02092080    RA =    0.98955067
         J =  44    P =    0.02121137    RA =    0.98768135
         J =  45    P =    0.02150193    RA =    0.98551251
         J =  46    P =    0.02179250    RA =    0.98300210
         J =  47    P =    0.02208307    RA =    0.98010318
         J =  48    P =    0.02237363    RA =    0.97676349
         J =  49    P =    0.02266420    RA =    0.97292515
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                  FOR PLATE WITH NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0040
               HALF SPECIMEN MODEL INPUT
      KC =    0.00100000
    BETA =    0.10000000
   ALPHA =   10.00000000
    PBAR =    0.03485000
      NE =  482
  ALPHA2 =   12.00000000
   BETAA =    0.03074947
       J =   1    P =    0.00871700    RA =     0.99999973
       J =   2    P =    0.00900757    RA =     0.99999960
       J =   3    P =    0.00929813    RA =     0.99999942
       J =   4    P =    0.00958870    RA =     0.99999915
       J =   5    P =    0.00987927    RA =     0.99999879
       J =   6    P =    0.01016983    RA =     0.99999829
       J =   7    P =    0.01046040    RA =     0.99999760
       J =   8    P =    0.01075097    RA =     0.99999666
       J =   9    P =    0.01104153    RA =     0.99999540
       J =  10    P =    0.01133210    RA =     0.99999372
       J =  11    P =    0.01162267    RA =     0.99999150
       J =  12    P =    0.01191323    RA =     0.99998856
       J =  13    P =    0.01220380    RA =     0.99998473
       J =  14    P =    0.01249437    RA =     0.99997975
       J =  15    P =    0.01278493    RA =     0.99997331
       J =  16    P =    0.01307550    RA =     0.99996505
       J =  17    P =    0.01336607    RA =     0.99995450
       J =  18    P =    0.01365663    RA =     0.99994111
       J =  19    P =    0.01394720    RA =     0.99992418
       J =  20    P =    0.01423777    RA =     0.99990290
       J =  21    P =    0.01452833    RA =     0.99987626
       J =  22    P =    0.01481890    RA =     0.99984307
       J =  23    P =    0.01510947    RA =     0.99980190
       J =  24    P =    0.01540003    RA =     0.99975103
       J =  25    P =    0.01569060    RA =     0.99968843
       J =  26    P =    0.01598117    RA =     0.99961170
       J =  27    P =    0.01627173    RA =     0.99951800
       J =  28    P =    0.01656230    RA =     0.99940397
       J =  29    P =    0.01685287    RA =     0.99926570
       J =  30    P =    0.01714343    RA =     0.99909858
       J =  31    P =    0.01743400    RA =     0.99889726
       J =  32    P =    0.01772457    RA =     0.99865549
       J =  33    P =    0.01801513    RA =     0.99836604
       J =  34    P =    0.01830570    RA =     0.99802051
       J =  35    P =    0.01859627    RA =     0.99760923
       J =  36    P =    0.01888683    RA =     0.99712106
       J =  37    P =    0.01917740    RA =     0.99654321
       J =  38    P =    0.01946797    RA =     0.99586101
       J =  39    P =    0.01975853    RA =     0.99505770
       J =  40    P =    0.02004910    RA =     0.99411420
       J =  41    P =    0.02033967    RA =     0.99300880
       J =  42    P =    0.02063023    RA =     0.99171690
       J =  43    P =    0.02092080    RA =     0.99021067
       J =  44    P =    0.02121137    RA =     0.98845873
       J =  45    P =    0.02150193    RA =     0.98642581
       J =  46    P =    0.02179250    RA =     0.98407239
       J =  47    P =    0.02208307    RA =     0.98135125
       J =  48    P =    0.02237363    RA =     0.97822221
       J =  49    P =    0.02266420    RA =     0.97462159
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITH NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
                HALF SPECIMEN MODEL INPUT
       KC =    0.00100000
     BETA =    0.10000000
    ALPHA =   10.00000000
     PBAR =    0.08704500
       NE =  482
   ALPHA2 =   12.00000000
    BETAA =    0.03111023
         J =    1    P =    0.00871700    RA =    0.99999977
         J =    2    P =    0.00900757    RA =    0.99999965
         J =    3    P =    0.00929813    RA =    0.99999949
         J =    4    P =    0.00958870    RA =    0.99999927
         J =    5    P =    0.00987927    RA =    0.99999895
         J =    6    P =    0.01016983    RA =    0.99999851
         J =    7    P =    0.01046040    RA =    0.99999791
         J =    8    P =    0.01075097    RA =    0.99999710
         J =    9    P =    0.01104153    RA =    0.99999601
         J =   10    P =    0.01133210    RA =    0.99999454
         J =   11    P =    0.01162267    RA =    0.99999261
         J =   12    P =    0.01191323    RA =    0.99999006
         J =   13    P =    0.01220380    RA =    0.99998672
         J =   14    P =    0.01249437    RA =    0.99998239
         J =   15    P =    0.01278493    RA =    0.99997680
         J =   16    P =    0.01307550    RA =    0.99996962
         J =   17    P =    0.01336607    RA =    0.99996045
         J =   18    P =    0.01365663    RA =    0.99994880
         J =   19    P =    0.01394720    RA =    0.99993408
         J =   20    P =    0.01423777    RA =    0.99991558
         J =   21    P =    0.01452833    RA =    0.99989242
         J =   22    P =    0.01481890    RA =    0.99986357
         J =   23    P =    0.01510947    RA =    0.99982777
         J =   24    P =    0.01540003    RA =    0.99978354
         J =   25    P =    0.01569060    RA =    0.99972912
         J =   26    P =    0.01598117    RA =    0.99966241
         J =   27    P =    0.01627173    RA =    0.99958094
         J =   28    P =    0.01656230    RA =    0.99948180
         J =   29    P =    0.01685287    RA =    0.99936158
         J =   30    P =    0.01714343    RA =    0.99921627
         J =   31    P =    0.01743400    RA =    0.99904122
         J =   32    P =    0.01772457    RA =    0.99883100
         J =   33    P =    0.01801513    RA =    0.99857930
         J =   34    P =    0.01830570    RA =    0.99827883
         J =   35    P =    0.01859627    RA =    0.99792117
         J =   36    P =    0.01888683    RA =    0.99749601
         J =   37    P =    0.01917740    RA =    0.99699403
         J =   38    P =    0.01946797    RA =    0.99640063
         J =   39    P =    0.01975853    RA =    0.99570183
         J =   40    P =    0.02004910    RA =    0.99488098
         J =   41    P =    0.02033967    RA =    0.99391915
         J =   42    P =    0.02063023    RA =    0.99279486
         J =   43    P =    0.02092080    RA =    0.99148380
         J =   44    P =    0.02121137    RA =    0.98995855
         J =   45    P =    0.02150193    RA =    0.98818824
         J =   46    P =    0.02179250    RA =    0.98613821
         J =   47    P =    0.02208307    RA =    0.98376971
         J =   48    P =    0.02237363    RA =    0.98103948
         J =   49    P =    0.02266420    RA =    0.97789045
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITH NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
                ENTIRE SPECIMEN MODEL INPUT
     KC =    0.00100000
   BETA =    0.10000000
  ALPHA =   10.00000000
   PBAR =    0.08702500
     NE = 592
 ALPHA2 =   12.00000000
  BETAA =    0.02887978
        J =    1    P =    0.00871700    RA =    0.99999943
        J =    2    P =    0.00900757    RA =    0.99999915
        J =    3    P =    0.00929813    RA =    0.99999876
        J =    4    P =    0.00958870    RA =    0.99999821
        J =    5    P =    0.00987927    RA =    0.99999743
        J =    6    P =    0.01016983    RA =    0.99999636
        J =    7    P =    0.01046040    RA =    0.99999490
        J =    8    P =    0.01075097    RA =    0.99999292
        J =    9    P =    0.01104153    RA =    0.99999025
        J =   10    P =    0.01133210    RA =    0.99998668
        J =   11    P =    0.01162267    RA =    0.99998195
        J =   12    P =    0.01191323    RA =    0.99997572
        J =   13    P =    0.01220380    RA =    0.99996758
        J =   14    P =    0.01249437    RA =    0.99995700
        J =   15    P =    0.01278493    RA =    0.99994334
        J =   16    P =    0.01307550    RA =    0.99992581
        J =   17    P =    0.01336607    RA =    0.99990342
        J =   18    P =    0.01365663    RA =    0.99987498
        J =   19    P =    0.01394720    RA =    0.99983905
        J =   20    P =    0.01423777    RA =    0.99979387
        J =   21    P =    0.01452833    RA =    0.99973733
        J =   22    P =    0.01481890    RA =    0.99966689
        J =   23    P =    0.01510947    RA =    0.99957949
        J =   24    P =    0.01540003    RA =    0.99947153
        J =   25    P =    0.01569060    RA =    0.99933869
        J =   26    P =    0.01598117    RA =    0.99917587
        J =   27    P =    0.01627173    RA =    0.99897704
        J =   28    P =    0.01656230    RA =    0.99873513
        J =   29    P =    0.01685287    RA =    0.99844181
        J =   30    P =    0.01714343    RA =    0.99808737
        J =   31    P =    0.01743400    RA =    0.99766047
        J =   32    P =    0.01772457    RA =    0.99714793
        J =   33    P =    0.01801513    RA =    0.99653447
        J =   34    P =    0.01830570    RA =    0.99580245
        J =   35    P =    0.01859627    RA =    0.99493150
        J =   36    P =    0.01888683    RA =    0.99389825
        J =   37    P =    0.01917740    RA =    0.99267590
        J =   38    P =    0.01946797    RA =    0.99123383
        J =   39    P =    0.01975853    RA =    0.98953721
        J =   40    P =    0.02004910    RA =    0.98754645
        J =   41    P =    0.02033967    RA =    0.98521678
        J =   42    P =    0.02063023    RA =    0.98249774
        J =   43    P =    0.02092080    RA =    0.97933261
        J =   44    P =    0.02121137    RA =    0.97565798
        J =   45    P =    0.02150193    RA =    0.97140315
        J =   46    P =    0.02179250    RA =    0.96648977
        J =   47    P =    0.02208307    RA =    0.96083139
        J =   48    P =    0.02237363    RA =    0.95433317
        J =   49    P =    0.02266420    RA =    0.94689176
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                FOR PLATE WITHOUT NOTCH
   WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0010
            ENTIRE SPECIMEN MODEL INPUT
      KC =    0.00100000
    BETA =    0.10000000
   ALPHA =   10.00000000
    PBAR =    0.00951200
      NE =  200
  ALPHA2 =   12.00000000
   BETAA =    0.04394803
       J =    1    P =    0.00871700    RA =    1.00000000
       J =    2    P =    0.00900757    RA =    0.99999999
       J =    3    P =    0.00929813    RA =    0.99999999
       J =    4    P =    0.00958870    RA =    0.99999999
       J =    5    P =    0.00987927    RA =    0.99999998
       J =    6    P =    0.01016983    RA =    0.99999998
       J =    7    P =    0.01046040    RA =    0.99999997
       J =    8    P =    0.01075097    RA =    0.99999995
       J =    9    P =    0.01104153    RA =    0.99999994
       J =   10    P =    0.01133210    RA =    0.99999991
       J =   11    P =    0.01162267    RA =    0.99999988
       J =   12    P =    0.01191323    RA =    0.99999984
       J =   13    P =    0.01220380    RA =    0.99999979
       J =   14    P =    0.01249437    RA =    0.99999972
       J =   15    P =    0.01278493    RA =    0.99999963
       J =   16    P =    0.01307550    RA =    0.99999952
       J =   17    P =    0.01336607    RA =    0.99999937
       J =   18    P =    0.01365663    RA =    0.99999919
       J =   19    P =    0.01394720    RA =    0.99999896
       J =   20    P =    0.01423777    RA =    0.99999866
       J =   21    P =    0.01452833    RA =    0.99999830
       J =   22    P =    0.01481890    RA =    0.99999784
       J =   23    P =    0.01510947    RA =    0.99999727
       J =   24    P =    0.01540003    RA =    0.99999657
       J =   25    P =    0.01569060    RA =    0.99999571
       J =   26    P =    0.01598117    RA =    0.99999465
       J =   27    P =    0.01627173    RA =    0.99999336
       J =   28    P =    0.01656230    RA =    0.99999179
       J =   29    P =    0.01685287    RA =    0.99998989
       J =   30    P =    0.01714343    RA =    0.99998759
       J =   31    P =    0.01743400    RA =    0.99998481
       J =   32    P =    0.01772457    RA =    0.99998148
       J =   33    P =    0.01801513    RA =    0.99997749
       J =   34    P =    0.01830570    RA =    0.99997273
       J =   35    P =    0.01859627    RA =    0.99996705
       J =   36    P =    0.01888683    RA =    0.99996031
       J =   37    P =    0.01917740    RA =    0.99995234
       J =   38    P =    0.01946797    RA =    0.99994291
       J =   39    P =    0.01975853    RA =    0.99993180
       J =   40    P =    0.02004910    RA =    0.99991875
       J =   41    P =    0.02033967    RA =    0.99990343
       J =   42    P =    0.02063023    RA =    0.99988551
       J =   43    P =    0.02092080    RA =    0.99986459
       J =   44    P =    0.02121137    RA =    0.99984022
       J =   45    P =    0.02150193    RA =    0.99981189
       J =   46    P =    0.02179250    RA =    0.99977901
       J =   47    P =    0.02208307    RA =    0.99974095
       J =   48    P =    0.02237363    RA =    0.99969696
       J =   49    P =    0.02266420    RA =    0.99964622
```

```
DATA OUTPUT FOR LINEARIZE SIZE EFFECT UNIAXIAL TENSILE STRESS
                    FOR PLATE WITHOUT NOTCH
    WHERE THE DISPLACEMENT BOUNDARY CONDITION IS    0.0100
                 ENTIRE SPECIMEN MODEL INPUT
     KC =    0.00100000
   BETA =    0.10000000
  ALPHA =   10.00000000
   PBAR =    0.09491000
     NE = 200
 ALPHA2 =   12.00000000
  BETAA =    0.04394802
       J =    1    P =    0.00871700    RA =    1.00000000
       J =    2    P =    0.00900757    RA =    0.99999999
       J =    3    P =    0.00929813    RA =    0.99999999
       J =    4    P =    0.00958870    RA =    0.99999999
       J =    5    P =    0.00987927    RA =    0.99999998
       J =    6    P =    0.01016983    RA =    0.99999998
       J =    7    P =    0.01046040    RA =    0.99999997
       J =    8    P =    0.01075097    RA =    0.99999995
       J =    9    P =    0.01104153    RA =    0.99999994
       J =   10    P =    0.01133210    RA =    0.99999991
       J =   11    P =    0.01162267    RA =    0.99999988
       J =   12    P =    0.01191323    RA =    0.99999984
       J =   13    P =    0.01220380    RA =    0.99999979
       J =   14    P =    0.01249437    RA =    0.99999972
       J =   15    P =    0.01278493    RA =    0.99999963
       J =   16    P =    0.01307550    RA =    0.99999952
       J =   17    P =    0.01336607    RA =    0.99999937
       J =   18    P =    0.01365663    RA =    0.99999919
       J =   19    P =    0.01394720    RA =    0.99999896
       J =   20    P =    0.01423777    RA =    0.99999866
       J =   21    P =    0.01452833    RA =    0.99999830
       J =   22    P =    0.01481890    RA =    0.99999784
       J =   23    P =    0.01510947    RA =    0.99999727
       J =   24    P =    0.01540003    RA =    0.99999657
       J =   25    P =    0.01569060    RA =    0.99999571
       J =   26    P =    0.01598117    RA =    0.99999465
       J =   27    P =    0.01627173    RA =    0.99999336
       J =   28    P =    0.01656230    RA =    0.99999179
       J =   29    P =    0.01685287    RA =    0.99998989
       J =   30    P =    0.01714343    RA =    0.99998759
       J =   31    P =    0.01743400    RA =    0.99998481
       J =   32    P =    0.01772457    RA =    0.99998148
       J =   33    P =    0.01801513    RA =    0.99997749
       J =   34    P =    0.01830570    RA =    0.99997273
       J =   35    P =    0.01859627    RA =    0.99996705
       J =   36    P =    0.01888683    RA =    0.99996031
       J =   37    P =    0.01917740    RA =    0.99995234
       J =   38    P =    0.01946797    RA =    0.99994291
       J =   39    P =    0.01975853    RA =    0.99993180
       J =   40    P =    0.02004910    RA =    0.99991875
       J =   41    P =    0.02033967    RA =    0.99990343
       J =   42    P =    0.02063023    RA =    0.99988551
       J =   43    P =    0.02092080    RA =    0.99986459
       J =   44    P =    0.02121137    RA =    0.99984022
       J =   45    P =    0.02150193    RA =    0.99981189
       J =   46    P =    0.02179250    RA =    0.99977901
       J =   47    P =    0.02208307    RA =    0.99974095
       J =   48    P =    0.02237363    RA =    0.99969696
       J =   49    P =    0.02266420    RA =    0.99964622
```

APPENDIX C

COMPUTER PROGRAMS FOR CONVERTING FINITE ELEMENT (NIKE2D) PROGRAM OUTPUT TO BE STATISTICAL RELIABILITY COMPUTER PROGRAM INPUT

```
C
C***********************************************************************
C
C        PROGRAM: CONVERT NIKE2D OUTPUT TO BE STATISICAL INPUT
C
C                 FOR 1PT. INTEGRATION ENTIRE SPECIMEN MODEL ONLY
C
C***********************************************************************
C
C***********************************************************************
C
      DIMENSION XL(594),XW(594),
      BYTE A(30)
      TYPE*,'ENTER FILE CONTAINING NIKE2D DATA OUTPUT'
      READ (5,500) A
  500 FORMAT(30A1)
      OPEN(UNIT=5, FILE=A, STATUS='OLD')
      OPEN(UNIT=6, FILE='CC.DAT', STATUS='NEW')
      WRITE(6,50)
      NE=592
      NP=NE/10+1
       DO 100 M=1,18
          XL(M)=.1658334
          XW(M)=.095
  100  CONTINUE
       DO 101 M=19,36
          XL(M)=.0995
          XW(M)=.095
  101  CONTINUE
       DO 102 M=37,132
          XL(M)=.024875
          XW(M)=.095
  102  CONTINUE
       DO 103 M=133,150
          XL(M)=.0995
          XW(M)=.095
  103  CONTINUE
       DO 104 M=151,168
          XL(M)=.1658334
          XW(M)=.095
  104  CONTINUE
       DO 105 M=169,200
          XL(M)=.1658334
          XW(M)=.024875
  105  CONTINUE
       DO 106 M=201,216
          XL(M)=.0995
          XW(M)=.024875
  106  CONTINUE
       DO 107 M=217,232
          XL(M)=.024875
          XW(M)=.024875
  107  CONTINUE
       DO 108 M=233,296
          XL(M)=.0995
          XW(M)=.024875
  108  CONTINUE
       DO 109 M=297,316
          XL(M)=.1658334
```

```
         XW(M)=.024875
109   CONTINUE
      DO 110 M=317,328
         XL(M)=.1658334
         XW(M)=.024875
110   CONTINUE
      DO 111 M=329,360
         XL(M)=.0995
         XW(M)=.024875
111   CONTINUE
      DO 112 M=361,424
         XL(M)=.024875
         XW(M)=.024875
112   CONTINUE
      DO 113 M=425,456
         XL(M)=.0995
         XW(M)=.024875
113   CONTINUE
      DO 114 M=457,488
         XL(M)=.1658334
         XW(M)=.024875
114   CONTINUE
      DO 115 M=489,576
         XL(M)=.024875
         XW(M)=.024875
115   CONTINUE
      DO 116 M=577,592
         XL(M)=.024875
         XW(M)=.024875
116   CONTINUE
     DO 10 I=1,NP
        DO 15 J=1,10
                M=10*(I-1)+J
                IF(M.NE.NE) THEN
                      IF(J.EQ.10) THEN
                         READ(5,45) SIGY,SIGZ,SIGX,SIGYZ
                      ELSE
                         READ(5,35) SIGY,SIGZ,SIGX,SIGYZ
                      END IF
                ELSE
                   READ(5,30) SIGY,SIGZ,SIGX,SIGYZ
                   GO TO 55
                END IF
                WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 15       CONTINUE
 10  CONTINUE
 55  WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 30  FORMAT(18X,4E11.0)
 35  FORMAT(18X,4E11.0,////)
 40  FORMAT(3X,I5,2F11.7,4E12.4)
 45  FORMAT(18X,4E11.0,////////////)
 50  FORMAT(1X,'ELEMENT NO.',4X,'L',10X,'W',7X,'SIGY',8X,'SIGZ'
    *,8X,'SIGX',7X,'SIGYZ',/)
     STOP
     END
```

```
C************************************************************
C
C************************************************************
C
C     PROGRAM: CONVERT NIKE2D OUTPUT TO BE STATISTICAL INPUT
C
C              FOR 4PT. INTEGRATION HALF SPECIMEN MODEL ONLY
C
C************************************************************
C
C************************************************************
C
      DIMENSION XL(1928),XW(1928)
      BYTE A(30)
      TYPE*,'ENTER FILE CONTAINING NIKE2D OUTPUT'
      READ(5,300) A
  500 FORMAT(30A1)
      OPEN(UNIT=5, FILE=A, STATUS='OLD')
      OPEN(UNIT=6, FILE='BB.DAT', STATUS='NEW')
      WRITE(6,50)
      NE=482
      NE4=NE*4
      NP=NE4/40+1
        DO 100 M=1,100
           XL(M)=.04975
           XW(M)=.02850
  100   CONTINUE
        DO 101 M=101,220
           XL(M)=.024875
           XW(M)=.028500
  101   CONTINUE
        DO 102 M=211,540
           XL(M)=.0124375
           XW(M)=.0285000
  102   CONTINUE
        DO 103 M=541,660
           XL(M)=.024875
           XW(M)=.028500
  103   CONTINUE
        DO 104 M=661,760
           XL(M)=.04975
           XW(M)=.02850
  104   CONTINUE
        DO 105 M=761,920
           XL(M)=.04975
           XW(M)=.0124375
  105   CONTINUE
        DO 106 M=921,1112
           XL(M)=.024875
           XW(M)=.0124375
  106   CONTINUE
        DO 107 M=1113,1368
           XL(M)=.0124375
           XW(M)=.0124375
  107   CONTINUE
        DO 108 M=1369,1560
           XL(M)=.024875
           XW(M)=.0124375
  108   CONTINUE
        DO 109 M=1561,1720
```

```
          XL(M)=.04975
          XW(M)=.0124375
109   CONTINUE
      DO 110 M=1721,1896
          XL(M)=.0124375
          XW(M)=.0124375
110   CONTINUE
      DO 111 M=1897,1928
          XL(M)=.0124375
          XW(M)=.0124375
111   CONTINUE
     DO 10 I=1,NP
        DO 15 J=1,10
           DO 20 K=1,4
              M=40*(I-1)+4*(J-1)+K
              IF(M.NE.NE4) THEN
                 IF(K.EQ.4) THEN
                    IF(J.EQ.10) THEN
                       READ(5,45) SIGY,SIGZ,SIGX,SIGYZ
                    ELSE
                       READ(5,35) SIGY,SIGZ,SIGX,SIGYZ
                    END IF
                 ELSE
                    READ(5,30) SIGY,SIGZ,SIGX,SIGYZ
                 END IF
              ELSE
                 READ(5,30) SIGY,SIGZ,SIGX,SIGYZ
                 GO TO 55
              END IF
              WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 20        CONTINUE
 15     CONTINUE
 10  CONTINUE
 55  WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 30  FORMAT(18X,4E11.0)
 35  FORMAT(18X,4E11.0,/)
 40  FORMAT(3X,I5,2F11.7,4E12.4)
 45  FORMAT(18X,4E11.0,//////////)
 50  FORMAT(1X,'ELEMENT NO.',4X,'L',10X,'W',7X,'SIGY',8X,'SIGZ'
    *,8X,'SIGX',7X,'SIGYZ',/)
     STOP
     END
```

```
C***********************************************************
C
C***********************************************************
C
C     PROGRAM: CONVERT NIKE2D OUTPUT TO BE STATISTICAL INPUT
C
C              FOR 1PT. INTEGRATION HALF SPECIMEN MODEL ONLY
C
C***********************************************************
C
C***********************************************************
C
      DIMENSION XL(482),XW(482)
      BYTE A(30)
      TYPE*,'FILE CONTAINING NIKE2D DATA OUTPUT'
      READ(5,500) A
  500 FORMAT(30A1)
      OPEN(UNIT=5, FILE=A, STATUS='OLD')
      OPEN(UNIT=6, FILE='BB.DAT', STATUS='NEW')
      WRITE(6,50)
      NE=482
      NP=NE/10+1
       DO 100 M=1,25
          XL(M)=.0995
          XW(M)=.0570
  100  CONTINUE
       DO 101 M=26,55
          XL(M)=.04975
          XW(M)=.057
  101  CONTINUE
       DO 102 M=56,135
          XL(M)=.024875
          XW(M)=.0570
  102  CONTINUE
       DO 103 M=136,165
          XL(M)=.04975
          XW(M)=.0570
  103  CONTINUE
       DO 104 M=166,190
          XL(M)=.0995
          XW(M)=.0570
  104  CONTINUE
       DO 105 M=191,230
          XL(M)=.0995
          XW(M)=.024875
  105  CONTINUE
       DO 106 M=231,278
          XL(M)=.04975
          XW(M)=.024875
  106  CONTINUE
       DO 107 M=279,342
          XL(M)=.024875
          XW(M)=.024875
  107  CONTINUE
       DO 108 M=343,390
          XL(M)=.04975
          XW(M)=.024875
  108  CONTINUE
       DO 109 M=391,430
          XL(M)=.0995
```

```
        XW(M)=.024875
109  CONTINUE
     DO 110 M=431,474
        XL(M)=.024875
        XW(M)=.024875
110  CONTINUE
     DO 111 M=475,482
        XL(M)=.024875
        XW(M)=.024875
111  CONTINUE
    DO 10 I=1,NP
       DO 15 J=1,10
             M=10*(I-1)+J
             IF(M.NE.NE) THEN
                   IF(J.EQ.10) THEN
                      READ(5,45) SIGY,SIGZ,SIGX,SIGYZ
                   ELSE
                      READ(5,35) SIGY,SIGZ,SIGX,SIGYZ
                   END IF
             ELSE
                READ(5,30) SIGY,SIGZ,SIGX,SIGYZ
                GO TO 55
             END IF
             WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 15    CONTINUE
 10 CONTINUE
 55 WRITE(6,40) M,XL(M),XW(M),SIGY,SIGZ,SIGX,SIGYZ
 30 FORMAT(18X,4E11.0)
 35 FORMAT(18X,4E11.0,////)
 40 FORMAT(3X,I5,2F11.7,4E12.4)
 45 FORMAT(18X,4E11.0,/////////////)
 50 FORMAT(1X,'ELEMENT NO.',4X,'L',10X,'W',7X,'SIGY',8X,'SIGZ'
   *,8X,'SIGX',7X,'SIGYZ',/)
    STOP
    END
```

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